Siemens Competition
Math : Science : Technology
National Finalist

Names: Adhya Beesam, Shriya Beesam
High School: Plano East Senior High School
Mentor: Julie Baker
Project Title: Linked Neuro-Fuzzy Inference System: A Novel Approach to Schizophrenia Diagnosis

Schizophrenia is a mental disorder that drastically alters a person's perception and actions until the patient becomes harmful to oneself or to others. The aim of this project was to develop a medical diagnostic inference system to accurately predict the likelihood of a patient having schizophrenia. Based on the PANSS psychiatric assessment results and MRI neuroimaging data, a comprehensive diagnostic tool was created. Three fuzzy logic systems and an ANFIS system were made. The PANSS system determined clusters of PANSS questions and calculated the likelihood based on the score for each cluster. The MRI system segmented the MRIs into grey matter, white matter, and cerebrospinal fluid, and the likelihood was determined based on the volumes of each segment. Initially, a linked fuzzy system was created that took the PANSS and MRI systems and created an overall likelihood based on their outcomes. Later, an Adaptive Neuro-Fuzzy Inference System was created using the same inputs and was determined to have a higher accuracy than the fuzzy system. This project is a tool that can be utilized by psychiatrists to solidify the diagnosis process and hopefully spur an advancement in technology and methods utilized for mental illnesses worldwide.

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National Finalist

Names: Katherine Cao, Alice Wu, & William Hu
High School: Homestead High School, Half Hollow Hills High School West, & Saratoga High School
Mentors: Miriam Rafailovich & Adriana Pinkas-Sarafova, Stony Brook University
Project Title: *Characterizing Novel, Spun-Cast PLA/Polystyrene Substrates of Differential Nanoscale Surface Topographies and Optimizing Cell-Plating Density to Promote Dental Pulp Stem Cell Proliferation and Differentiation in vitro*

Dental pulp stem cells (DPSCs) hold tremendous potential in tissue and bone regeneration on in vitro substrates. This study evaluated the effects of nanoscale surface topography and cell-plating density on DPSC proliferation and differentiation. Polylactic acid (PLA), a highly biocompatible polymer, was spun-cast with polystyrene (PS) onto silicon wafers. The PS was removed through dissolution to construct varying surface topographies, before DPSCs were plated onto the substrates to study cell behavior. While bi-polymer blends have been studied in previous experiments, our technique in the creation of polymer thin film surfaces is novel. Atomic force microscopy was used to characterize the surfaces and confocal microscopy revealed the favorable spreading of actin filaments over porous surfaces. Based on early-stage proliferation, higher cell- plating densities were found to correspond with higher plating efficiencies. Scanning electron microscopy verified the biomineralization of the cells, and real-time polymerase chain reaction analysis identified the various differentiation markers of the DPSCs. All surfaces were able to induce biomineralization; however, the PLA-MG 1:PS(45.8K) 1 surface induced the most osteogenic differentiation, likely due to its similarity to dentin. The implications of our findings hold promise in the field of regenerative medicine.

Siemens Competition
Math : Science : Technology
National Finalist

Names: Nikhil Cheerla and Anika Cheerla
High School: Monta Vista High School, Cupertino CA
Mentor: Dr. Andrew Beck and Dayong Wang
Project Title: Mitosis Detection And Tumor Grading Using Deep Convolutional Neural Networks

Analyzing mitosis proliferation is crucial to physician grading of tumor severity and prognosis. Despite the time and effort poured into automated mitosis detection, no systems have been able to perform at the level of skilled pathologists, who manually examine slide images for mitotic cells.

We build a 100-layer deep GoogLeNet-derived mitosis detector with aggressive data augmentation, and train it with our novel multi-stage bootstrapping algorithm to extract meaningful training examples from highly imbalanced data. Our deep convolutional neural network achieves an F1 score of 0.85 on the 717-image TUPAC dataset. This trained model also generalizes well, surpassing the best F1-scores obtained in previous mitosis competitions.

We then develop a pipeline to grade whole slide images using an intuitive ROI selection algorithm and the trained mitosis detector. The genes identified by our continuous mitosis scores outperform pathologist scores in their association to cancer and cell cycle functions/pathways. Finally, we build a gene-level model to predict the mitosis scores from RNA-sequence data. From this model, we extract 10 gene predictions possibly linked to tumor mitotic activity.

We hope our research is a step towards a future where physicians use precise, deep-learning- enabled analyses of mitotic activity to diagnose and treat patients.

Siemens Competition
Math : Science : Technology
National Finalist

Names: Vineet Edupuganti
High School: Oregon Episcopal School
Mentor: Dr. Raj Solanki
Project Title: Development of a High-Performance Biodegradable Battery for Transient Electronics

Traditionally, emphasis has been placed on durable, long-lasting electronics. However, electronics that are meant to intentionally degrade over time can actually have significant practical applications. Biodegradable, or transient, electronics would open up opportunities in the field of medical implants, where the need for surgical removal of devices could be eliminated. Environmental sensors and, eventually, consumer electronics would also greatly benefit from this technology. An essential component of transient electronics is the battery, which serves as a biodegradable power source. This work developed a biodegradable battery using a magnesium-based anode and an iron cathode. Discharge tests showed that magnesium alloy AZ31 extends battery lifetime by over six times, as compared to pure magnesium. With AZ31, the maximum power and capacity of the fabricated device were 67 μW and 5.2 mAh, respectively, though the anode area was just 0.8 cm^2. An equivalent circuit model was developed that accurately captured device behavior, taking into account its intentional degradation, allowing for application-based optimization without extensive experimental testing. The size of the device and the power it produces are in accordance with expected levels for low-power transient systems, indicating that the batteries developed in this research are sufficient for deployment in several application areas.

Siemens Competition
Math : Science : Technology
National 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
National Finalist

Names: Louis Golowich and Richard Zhou
High School: Lexington High School
Mentor: Chiheon Kim
Project Title: Maximum Size of a Family of Pairwise Graph-Different Permutations

Two permutations of the vertices of a graph G are called G-different if there exists an index i such that i-th entry of the two permutations form an edge in G. We bound or determine the maximum size of a family of pairwise G-different permutations for various graphs G. This problem is motivated by its relation to the Shannon capacity of a graph. We show that for all balanced bipartite graphs G of order n with minimum degree $n/2 - o(n)$, the maximum number of pairwise G-different permutations is $2^{(1-o(1))n}$. We also present examples of bipartite graphs G with maximum degree $O(\log_2 n)$ that have this property. We explore the problem of bounding the maximum size of a family of pairwise $M(n)$-different permutations, where $M(n)$ denotes the graph of $n/2$ independent edges; we determine the exact value for $M(4)$, and present some asymptotic bounds relating to pairwise $M(n)$-different families of permutations.

Siemens Competition
Math : Science : Technology
National Finalist

Names: Blake Hord
High School: Dobbs Ferry High School
Mentor: Dr. Wladimir Lyra

Project Title: High Mass Planet Spiral Shocks as a Source of Infrared Emission in Protoplanetary Disks

Recent observations of the protoplanetary disk around the Herbig Ae star HD 100546 by Currie et al. (2014) showed two bright features in the infrared L' band (3.5 microns) at about 50 AU. The features showed little polarization, which suggested that the emission was thermal. While one appeared at the location of a confirmed exoplanet, the other was not explained. A recent hydrodynamic model of the effects of shocks induced by a high mass planet (Lyra et al. 2016) showed that these shocks heat regions around the planet to relatively high temperatures (~500 K). These shocks could have been the source of the excess infrared emission in the disk around HD 100546. To determine a possible source of emission, the observational signatures of a high mass planet causing shock heating throughout its disk are explored. The RADMC-3D code was used to perform dust radiative transfer calculations on the disk models of Lyra et al. (2016). This code used a more realistic cooling of the hot lobes and the spirals brought about by shock heating. It was found that the synthetic image generated by RADMC-3D at 3.5 microns matched the general morphology of the second infrared source, meaning that there could have been evidence for a high mass planet causing the second source. Thus, shocks generated by high mass planets may be able to explain the source of the infrared emission around HD 100546. This evidence indicated that the possible planet causing the emission would be at approximately 50 AU, although a more thorough treatment of the specific conditions of HD 100546 was warranted in order to confirm this.

Siemens Competition
Math : Science : Technology
National Finalist

Names: Prateek Kalakuntla
High School: Texas Academy of Math and Science
Mentor: Mohammad Omary
Project Title: A Novel Luminescent Gold(I)-Based Hybrid System for Sensing Mercury

A vast majority of the 11 million people at risk for mercury poisoning, and the neurodegenerative effects that accompany this toxic heavy metal, inhabit developing countries where new methods of artisanal small-scale gold mining (ASGM) have greatly increased the concentration of mercury in local water sources; however, current mercury sensors are either too unwieldy or too costly to be used in these regions. Using a 3-amino-1,2,4-triazole-5-carboxylic acid in conjunction with a gold(I) precursor in a 1% molecular weight chitosan matrix, I have developed a novel hybrid-phosphorescent system that is sensitive to mercury. In order to quantify system's luminescence, I used a PTI 4000 spectrofluorometer, this data enabled me to optimize the system's sensitivity to mercury and increase its general utility. My system can sense concentrations of mercury between 0.3 and 300 parts per million (ppm). By titrating specific quantities of ethylenediaminetetraacetic acid (EDTA) into the system and synthesizing it in a phosphate-based saline buffer, I have rendered it completely reversible and stable at pH values between 4.0 and 10.0. This system has proved to be biologically-friendly, effective in fresh water media, easy-to-produce, and low-cost, allowing it to fill an important niche in mercury-sensing ecosystem – hence warranting patent filing.

Siemens Competition
Math : Science : Technology
National 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 $Aβ_{42}$/Exos aggregates and revealed for the first time increased neuronal structural damage and death as compared to $Aβ_{42}$ oligomers or exosomes alone. Furthermore, using immunocytochemistry, we detected intracellular labeling for ceramide and PAR-4 in neurons exposed to $Aβ_{42}$/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
National Finalist

Names: Yoshihiro Saito and Lauryn Wu
High School: Marriotts Ridge High School and Thomas Jefferson High School for Science and Technology
Mentor: Dr. Xuan Luo
Project Title: *New Discovery of Large Bulk Band Gap Topological Insulators in Chemically Functionalized Two-Dimensional Compounds* (Physics)

Two dimensional (2D) topological insulators (TI) have been a point of focus in recent research in condensed matter physics because of the potential applications of their robust, unique properties. TIs have gapless metallic states at the edge, but behave like ordinary insulators in the bulk, so TIs are able to conduct electricity only at the edge without backscattering. However, the lack of large bulk band gap TIs is hindering its advancement in scientific research and is preventing its use at room temperature. Based on first-principles calculations implemented in the ABINIT package, the geometric, electronic, and topological properties of $TlPX_2$, $TlAsX_2$, and $BiSbX_2$ (X = H, F, Cl, Br, I) systems were analyzed. We discovered $TlPX_2$, $TlAsX_2$, and $BiSbX_2$ to be TIs with bulk band gaps as large as 0.43 eV, and thus, suitable for room temperature applications. These newly discovered 2D TIs fill in the blanks of TI research and make a significant contribution to the field of condensed matter physics and materials science.

Siemens Competition
Math : Science : Technology
National Finalist

Name: Manan Shah
High School: The Harker School
Mentor: Dr. Dayong Wang
Project Title: Deep Learning Assessment of Tumor Proliferation in Histopathological Images for Categorical and Molecular Breast Cancer Severity Diagnosis

The emergence of high-throughput histopathological images over the past decade provides new opportunities for computational techniques to study cancerous tumors. Current analysis of tumor proliferation, the most salient prognostic biomarker for invasive breast cancer, is limited to subjective mitosis counting by pathologists in localized regions of tissue images and fails to address additional features critical to holistic analysis. Objective reports require expensive molecular RNA expression tests which are infeasible in developing countries. This study presents the first data-driven integrative approach to characterize the severity of tumor growth and spread on a categorical and molecular level, utilizing multiple biologically salient deep learning classifiers to develop a comprehensive prognostic model. Our approach achieves pathologist-level performance on three-class categorical tumor severity prediction. It additionally pioneers prediction of molecular expression data from a tissue image, obtaining a Spearman's rank correlation coefficient of 0.60 ($p < 0.001$) with *ex vivo* RNA molecular expression data. Furthermore, our novel framework is applied to identify over 200 unprecedented biomarkers critical to the accurate assessment of tumor proliferation, validating our proposed integrative pipeline as the first to holistically and objectively analyze histopathological images. Our generalizable cost-effective model can be applied to diagnosis, prognosis, and identification of biomarkers associated with a wide range of cancerous diseases and phenotypes.

Siemens Competition
Math : Science : Technology
National Finalist

Names: Pranav Sivakumar
High School: Illinois Mathematics and Science Academy
Mentor: Dr. Donald York
Project Title: Searches for Almost Dark Galaxies in Blank Sky Fields with the Sloan Digital Sky Survey

A class of dwarf galaxies known as Almost Dark Galaxies (ADGs), which are dominated by dark matter and give off little to no starlight, are the ideal laboratories to study the mystery of dark matter. I report results from two distinct approaches developed for detection of ADGs in the Sloan Digital Sky Survey (SDSS). The first approach selects regions called bounding boxes with an uneven light distribution not centered on bright objects. The bounding box approach uses color-cut criteria derived from Leo P, one of the best-known ADGs. This method produced 3,948 targets within SDSS sky coverage; 25 candidates remained following visual review and analysis. The complementary approach targeted ADGs producing absorption lines in quasar spectra by relaxing the Leo P-based color criteria but restricting targets to galaxies with a quasar within 30 arcseconds of the target. The second approach generated 4,516 targets, from which 110 potential candidates were identified based on characteristics of absorption lines of ionized calcium seen in the spectra of background quasars. The most exciting results so far are the confirmations of Leo P and AGC 198691. Plans are underway to obtain narrow-band 21 cm long-integration spectra using the MeerKAT radio telescope to confirm the candidates.