Siemens Competition
Math : Science : Technology
Regional Finalist

Name: Neil Wary
High School: Illinois Mathematics and Science Academy
Mentor: Dr. Kishore K. Wary
Project Title: Connecting the Chromatin Remodeler CHD7 in the Regulation of CHARGE Syndrome and Autism

A strong hypothesis is emerging in connection with the CHD7 protein: dysfunction of this protein might play a key role in CHARGE syndrome, autism, and several cardiovascular diseases. As there is no cellular or animal model system to study the function of CHD7, the goal of this investigation was to create the disease in-a-dish by the use of CRISPR/Cas9 technology to edit the CHD7 gene in human aortic endothelial cells (hAECs). Accordingly, we generated lentivirus particles encoding CRISPR/Cas9-CHD7 single guide(sg)RNA in an all-in-one vector, and transduced hAECs with viral particles. We selected clones that were puromycin resistant. These cells were passaged for 5-6 times in puromycin containing media. DNAs were prepared from these clones, and CRISPR/Cas9 mediated *CHD7* mutations were confirmed by Sanger DNA sequencing. Decreased expression of CHD7 was confirmed by Western blot analyses. We showed that haploinsufficiency of CHD7 mediate decreased expression VEGFR2/FLK1, but increased expression of p53 and p21 cell cycle inhibitors, thereby inducing apoptosis of these cells. These findings indicate that CHD7 protein regulates the expression of VEGFR2/FLK1 in cardiovascular cells, and therefore its downregulation is likely to affect several different cell types, including the fate of neuronal cells that depend on VEGFR2 signaling. We propose that altered CHD7 and VEGFR2/FLK1 function is the key to CHARGE, a subset of autism, and cardiovascular diseases.

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Names: Nabeel Quryshi
High School: University School of Milwaukee
Mentor: Dr. Andreas Beyer
Project Title: Role of Telomerase in Vascular Function and Exploration of Mitochondrial Dynamics: A Novel Approach to Treatment of Vascular Dysfunction

Coronary Artery Disease (CAD), an aging related detriment, is the most common cause of mortality in the world. In addition, chemotherapy jeopardizes cardiovascular integrity and was shown to be interconnected with CAD via RNAseq. Telomerase, an anti-aging related enzyme, is a nuclear derived telomere regulator and was hypothesized to mitigate the vascular effects of aforementioned ailments. Following creation of a specialized videomicrocopy apparatus, global activation of telomerase resulted in restored vascular function amidst CAD and chemotherapy. Separate from its conventional nuclear role, telomerase was shown to translocate to the mitochondria and preserve mitochondrial function. As global overexpression of telomerase is known to be oncogenic, a novel, clinically applicable mitochondrial telomerase decoy peptide was created in order to preserve therapeutic effects with minimal oncogenic activity. The decoy peptide restored vascular function and preserved cellular integrity amidst CAD, chemotherapy and vascular stressors. In order to accelerate telomerase-related drug development, a unique computational method using a developed at-home computational cluster was developed. Moreover, an ultra precise mechanistic mathematical model of mitochondrial dynamics was created in order to simulate and predict novel mitochondrial telomerase interactions as well as further explore mitochondrial systems. This multidisciplinary study presents a revolutionary mechanism to combat CAD and preserve vascular function amidst chemotherapy. Additionally, the developed platform technologies have implications with many other diseases, representing a promising advancement to the biomedical field.

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Names: Suraj Srinivasan
High School: Strongsville High School
Mentor: Dr. Andrew Shoffstall
Project Title: Development of a Mosquito-Inspired Insertion Guide to Prevent Flexible Intracortical Microelectrodes from Buckling during Implantation

Intracortical microelectrodes are essential tools in the rapidly growing neural electrophysiology and brain-computer interface (BCI) fields. The development of *flexible* intracortical microelectrodes has been a priority for researchers in efforts to increase biocompatibility and recording performance. However, these flexible probes must remain stiff enough to penetrate the brain tissue without buckling during implantation. Looking to nature, the mechanics of the mosquito bite allow its fascicle, a flexible tube merely 30 microns in diameter, to be inserted into the human skin with a bracing arm known as the labium.

This study details the development of a mosquito-inspired assistive insertion system which drastically reduces buckling. *In vitro* experimentation with laser-cut insertion guides in an agar gel model enabled successful insertion was achieved in 92% of the trials (versus 23% without). Buckling only occurred in 19% of the trials with the guide (versus 85% without). The rate of successful insertion was also increased in rat *in vivo* experimentation from 38% of trials to 100%. Furthermore, the guide demonstrated the ability to implant a flexible microelectrode through the tough and intact dura mater. Finally, compression force testing demonstrated over a 300% increase in the critical buckling force of the microelectrodes when utilizing the guide.

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Names: Julia M. Wang
High School: Ladue Horton Watkins High School
Mentor: Professor Lan Yang
Project Title: A Novel Technique for Monitoring Blood Pulse Shape with Packaged Whispering-Gallery-Mode Optical Micro-Toroids

Cardiovascular disease is the number one killer in the world. Measuring pulse shape and blood pressure continuously and safely could save lives by providing crucial early warnings of cardiovascular disease, but no existing sensor has these capabilities. To meet this imperative biomedical need, I have created a portable sensor made of whispering-gallery-mode (WGM) micro-toroids, which holds promise for unparalleled detection capabilities and widespread adoption due to its ultra-high sensitivity, small size, and low cost. Here, I detail the methods that I used to fabricate and characterize the WGM micro-toroids. I show that the micro-toroids can robustly measure pulse shape continuously in real time in a simulated lab setting. I also compare the responses of different simulated pulse shapes, which indicate important information about pressure. In addition, the micro-toroids were found to maintain a highly stable quality (Q) factor over time and provide reproducible measurements.

Siemens Competition
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Regional Finalist

Names: Haran Kumar
High School: Parkway West High School
Mentor: Michael Palmer
Project Title: JMM: Transpiling JavaScript to Rust

By historical accident, JavaScript is the language used to program the modern web, despite its inherent performance limitations. WebAssembly is a new bytecode format that runs in the browser and promises significant performance improvements over JavaScript. However, current solutions for compiling JavaScript to WebAssembly are limited, leaving developers to port existing JavaScript codebases to WebAssembly. JavaScript Minus Minus (JMM) is a subset of JavaScript that compiles to WebAssembly or native code via Rust. This study defines JMM and presents its compiler. Benchmarks provide evidence of the potential for substantial performance improvements over existing JavaScript code, suggesting the potential of this technology to make the web faster.

Siemens Competition
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Regional Finalist

Names: Kane Breuer, Thomas Breuer
High School: New Albany High School
Mentor: Cameron Best
Project Title: Development of a Novel Biological Therapeutic for Preventing the Formation of Pericardial Adhesions After Cardiothoracic Surgery

Problem: Pericardial adhesions increase morbidity and mortality after heart surgery.

Methods: We evaluated the role of lysosomal trafficking regulator (LYST) protein on the formation of pericardial adhesions after cardiothoracic surgery using a LYST-mutant mouse model. We used qualitative immunohistochemical methods to characterize the pericardial adhesion tissue. Next, we evaluated the ability of anti-LYST antibody to bind to LYST protein by incubating fluorescein isothiocyanate (FITC)-labeled anti-LYST antibody with cultured mouse macrophages. Finally, we compared the safety and efficacy of anti-LYST antibody versus control antibody to inhibit adhesion formation in our mouse model.

Results: We demonstrated that LYST-mutant mice exhibited significantly less adhesions compared to wild-type control mice. Qualitative immunohistochemical analysis of the pericardial tissue demonstrated that loss of LYST protein function inhibited macrophage infiltration and decreased angiogenesis. We demonstrated co- localization of FITC-labeled anti-LYST antibody in the intracellular regions of the macrophage where LYST is expressed. We showed that preoperative administration of anti-LYST antibody significantly reduced adhesion formation without increasing the number of post-operative complications or deaths compared to a control antibody.
Conclusions: Results of this pilot study suggest that anti-LYST antibody offers a potential novel strategy for preventing formation of pericardial adhesions after cardiothoracic surgery.

Siemens Competition
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Regional Finalist

Names: Daniel Zhang and Brandon Zhu
High School: Herbert Henry Dow High School
Mentor: Dr. Patrick Smith
Project Title: Release of Active Pharmaceuticals Using Capped Hyperbranched Polyesters

Medical professionals have struggled to develop delivery systems for active pharmaceutical ingredients (APIs) to mitigate inconsistent dosage and inconvenience from traditional forms of drug delivery. Sustained release of these APIs through covalent bonding to hyperbranched polyesters (HBPEs) can serve as a solution to this problem. HBPEs, covalently bonded to the APIs through esterification, are an ideal platform for sustained release because the release rate of the API can be manipulated by adjusting the hydrophilic/hydrophobic balance and solubility of the HBPE using different HBPE compositions. Further, these materials can be made with biodegradable and biobased monomers. HBPEs were synthesized with either hydroxyl or carboxyl end groups and were covalently bonded with the following APIs: naproxen, a nonsteroidal anti-inflammatory drug, salicylic acid, the metabolic product of aspirin, and hydrocortisone, a topical drug used for inflammation and swelling. In vitro enzymatic degradation of the hyperbranched polyesters bonded with APIs were performed using rat liver microsomes at 37 °C in phosphate buffer at a pH of 7.4. It was found that these APIs were released at a linear rate. Altering the composition of the HBPE, such as changing from a glycerol-adipic acid HBPE conjugate to a glycerol-succinic acid HBPE conjugate, significantly changed the release rate of the API, demonstrating that this HBPE platform can be used for sustained release of APIs and to control the rate of enzymatic release.

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Regional Finalist

Names: Sai Anantapantula and Arav Agarwal
High School: Northville High School
Mentor: Dr. Eddie Cheng
Project Title: Resiliency of the Shuffle-Cube in the Face of Link Deletion

Parallel computing networks allow for high speed performance and offer the advantage of improved connectivity and reliability, the major reason for their use in supercomputers. How well a certain network performs is directly related to its underlying structure, or its system topology, which is commonly represented by graphs. The hypercube is a popular interconnection network; however, it has many flaws including a large diameter and a low degree of fault tolerance with respect to node deletion. In our paper, we consider a stronger variant of the hypercube, the shuffle-cube, a recursively defined graph in which the next level is created by adding cross edges between 16 members of the previous level. Since matchings have been studied as the prominent measures of robustness in the event of link failures in parallel computing networks, we investigated the matching preclusion and conditional matching preclusion of the shuffle-cube. In our paper, we found several encouraging results regarding the fault tolerance of the shuffle-cube, showing that the deletion of a large number of edges still resulted in a graph with a perfect matching. Overall, we found that the shuffle-cube's robustness, speed and scalability make it an ideal candidate for future use in parallel computing networks.

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Regional Finalist

Names: Hanson Hao, Claudia Zhu
High School: Illinois Mathematics and Science Academy
Mentor: Dr. Saad El-Zanati
Project Title: A Computer-Aided Decomposition of the Complete Digraph into Orientations of K_4-e with a Double Edge

Let D be any of the 5 non-symmetric digraphs obtained by orienting the edges of K_4-e with a double edge (denoted thereafter by K_4-e*2). We obtain some (K_n^*,D) designs for small values of n where $n<36$ aided by a C++ program. The C++ program was able to verify nonexistence results as well as construct new (K_n^*,D) designs. It also used a memoization technique, where previous runs were stored and referenced, in order to reduce runtime. Furthermore, we establish necessary and sufficient conditions for the existence of a (K_n^*,D)-design for some of the general constructions using the aforementioned small cases and a "blow-up" construction. Partial results as well as some nonexistence results are established for the remaining digraphs. Future work on this project may be done by developing more of the partial results and improve the code to reduce both memory usage and runtime, possibly by the use of parallel processing.

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Regional Finalist

Names: Freddie Zhao, Spencer Liu, Chittesh Thavamani
High School: Troy High School
Mentor: Eddie Cheng
Project Title: A Study of the Vulnerability of Connectivity of Graphs: Strong Matching Preclusion of the Folded Petersen Cube

The strong matching preclusion number of a graph is the minimum number of vertices and/or edges whose deletion results in a graph that has neither perfect matchings nor almost perfect matchings. For many interconnection networks, the optimal sets are precisely those induced by a single vertex. This is an extension of the matching preclusion problem that was introduced by Park and Ihm. The class of arrangement graphs was introduced as a common generalization of the star graphs and alternating group graphs, and to provide an even richer class of interconnection networks. In this paper, the goal is to find the strong matching preclusion number of the folded Petersen cube FPQ(n, k) and to categorize all optimal strong matching preclusion sets of these graphs. We will also investigate the corresponding problem in a somewhat more general setup.