Siemens Competition
Math : Science : Technology
Regional Finalist

Names: Arjun Guru & Maya Guru
High School: The Altamont School
Mentor: Christopher Willey, M.D., Ph.D., University of Alabama at Birmingham
Project Title: *Determination of Activity of Kinases in Muscle-invasive Bladder Cancer Compared to adjacent Normal Bladder to Identify Drivers of Cancer Growth and Therapeutic Targets*

Problem: Muscle-invasive bladder cancer is a lethal cancer with no improvements in therapy for over 2 decades. The most important drivers of its growth are unclear. Studies have measured the quantity and mutations in kinase genes, RNA and proteins in cancer tissue since kinases are important drivers of cancer growth. None of the reported studies have measured the functional 'activity' of kinases in bladder cancer tissue.

Methods: We employed a novel methodology to measure functional kinase activity in muscle invasive bladder cancer and adjacent normal bladder (PamGene). This methodology measures the ability of lysates from fresh frozen tissue to phosphorylate substrate peptides and calculates the upstream kinases that are functionally active.

Results: The SRC family of kinases was the most active kinase in muscle-invasive bladder cancer compared to adjacent normal bladder tissue in 24 patients. Additionally, EGFR, PDGFR, CDK1 and PKC were highly active in cancer tissue.

Conclusion: In this first innovative study in the world to measure protein kinase 'activity' in muscle-invasive bladder cancer in comparison with adjacent normal bladder tissue, we identified multiple kinases that warrant further evaluation as

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Names: Priyanka Konan & Ritika Bharati
High School: Hamilton High School
Mentor: Dr. D Page Baluch of Arizona State University School of Life Sciences, Keck Laboratory
Project Title: *Observing The Capabilities Of The R9-caPep Peptide In Inhibiting Growth Ofnueroblastoma Cells*

Due to its involvement in DNA synthesis, regulation, and repair, proliferating cell nuclear antigen (PCNA) is crucial to retaining the integrity and stability of a genome. A certain isoform of PCNA (caPCNA) has been seen in many forms of cancer cells and absent in healthy cells. Previously, it has been demonstrated that the caPCNA-specific antigenic site lies between L126 and Y133- a region within inner domain of PCNA that is known to be a major binding site for many of PCNA's interacting proteins [28]. In this experiment, the experimenters hypothesized that protein-protein interactions would differ in cells that contain caPCNA as opposed to cells without caPCNA. To test this hypothesis, the experimenters designed a cell permeable peptide containing the sequence found in PCNA L126-Y133. The experimenters observed that this peptide selectively killed human neuroblastoma cells, especially those in which the MYCN gene, which has been reported to be associated with the formation of cancer in the past [30], is amplified. The peptide is able to block PCNA interactions in cancer cells because of its interference with DNA synthesis and DNA recombination, specifically, double strand DNA repair. This blockage results in the interference of the S phase in the cell reproduction cycle as well as an increase in DNA damage in cancer cells, which demonstrates a prospective use of this peptide for treating neuroblastoma- particularly for treatments of tumors with high MYCN levels.

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Regional Finalist

Names: Robert Luo & Helen Zhang
High School: Highland Park High School
Mentor: Mi Deng, UT Southwestern Medical Center
Project Title: *A Novel Therapy for the Treatment of Acute Myeloid Leukemia*

Acute myeloid leukemia (AML), as the most common adult acute leukemia, is a life-threatening disease characterized by uncontrolled proliferation and accumulation of white blood cells. The majority of patients relapse within 5 years, and no new therapies for AML have been approved for more than 30 years. Recent studies suggest that leukemia stem cells are responsible for the initiation, development, and relapse of AML, and depletion of both leukemia stem cells and mature leukemia cells is needed to eradicate this difficult disease. In our effort to identify new AML targets through bioinformatics analyses, we found that the expression of leukocyte immunoglobulin-like receptor family B4 (LILRB4), a cell surface receptor, inversely correlates with the overall survival of AML patients. To test the hypothesis that LILRB4 supports AML development, we first measured the expression of LILRB4 in AML patient leukemia cells by using the immunostaining and flow cytometry technique. We observed that LILRB4 is highly expressed on monocytic AML cells and can also be co-expressed with a leukemia stem cell marker CD34. This result suggests that LILRB4 can be expressed by both monocytic AML stem cells and mature leukemia cells. We then performed in vitro experiments to knockdown LILRB4 expression in human monocytic AML THP-1 cells using shRNA. We found that LILRB4 is essential for the growth of leukemia cells. Furthermore, from in vivo experiments we were able to show that an anti-LILRB4 blocking antibody is capable of eliminating human AML in a xenograft mouse model. Our study indicates that LILRB4 plays a key role in AML development and that anti-LILRB4 monoclonal antibodies are promising novel drug candidates for treating AML.

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Regional Finalist

Name: Neha Narayan
High School: Friendswood High School
Mentor: Hasna Baidouri
Project Title: *Magic Potion for Diabetic Infection: The effect of Omega-3 against E.coli infection in Diabetics*

Omega-3 polyunsaturated fatty acids (ω-3 PUFAs) are known for their beneficial effects in various organs. Diabetes is known to predispose patients to Escherichia coli (E.coli) infection in the colon increasing the incidence of colon cancer. The aim of this project is to determine if ω-3 PUFAs have a beneficial effect against E.coli infection in diabetics. Furthermore, to study the mechanism involved, it examines the role of antimicrobial peptides hBD-2 and LL-37.

Colonocytes grown in normal or high glucose media were treated with or without ω-3 PUFA (Docosahexaenoic acid/DHA). Cell supernatants were collected for antimicrobial assays using E.coli and lysate for mRNA analysis of hBD-2 and LL-37. Results indicated that DHA treated diabetic cells had lesser E.coli growth than control. RT-PCR demonstrated hBD-2 and LL-37 was higher in DHA treated cells, with greater effect in high glucose cells. Blocking hBD- 2 and LL-37 decreased the antimicrobial activity of DHA. In conclusion, results demonstrate that ω-3 PUFA revealed a significant antimicrobial activity against E.coli in high glucose environment and hBD-2 and LL-37 may in-part be responsible for its antimicrobial activity. The findings from this project suggest that ω-3 PUFA is a potential novel treatment for E.coli infection in diabetics.

Siemens Competition
Math : Science : Technology
Regional Finalist

Name: Edward Park
High School: Las Cruces High School
Mentor: Young Ho Park, New Mexico State University
Project Title: *Bio-Battery Utilizing Extracellular Charge Transfer of Exoelectrogenic Bacteria*

Simple, single chamber, mediator-less bio-batteries were engineered. Using metal reducing bacterium Shewanella oneidensis, we showed that a network of electrically conductive nanowires was produced in the bio-battery with the initial anoxic phase of inoculation and this network was associated with electricity generated. No significant electricity was produced in the bio-battery inoculated without the initial anoxic phase (control setup). Transmission electron microscopy (TEM) imaging revealed the network of nanowires linking cells-cells, wiring the entire length of the bio-battery. We tested the bio-battery with defined medium (M9) containing acetate and glucose. Unlike typical mediatorless MFCs, exoelectrogenic bacteria in this bio-battery don't need to be immobilized on the anode surface. The bio-battery operated without any cation specific membrane, additional feeding or pH control. Fed by the synthetic acetate wastewater, the power density of 3.1 mW/m2 was achieved from the bio-battery.

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Regional Finalist

Name: Sanjana Rane
High School: DuPont Manual High School
Mentor: Shunying Jin, University of Louisville
Project Title: *Effects of the Environmental Pollutant Acrolein on Renal Fibrosis*

Acrolein decreased Nuclear Factor-Erythroid derived protein 2 (NF-E2) protein expression in human-renal-tubular (HK-11) cells, induced HK-11 cell apoptosis and increased expression of pro-fibrotic Connective Tissue Growth Factor (CTGF) protein. Over-expression of NF-E2 ameliorated acrolein effects in HK-11 cells. Interestingly, NF-E2 was released in acrolein-treated HK-11 cell supernatants (Acr-sups). Danger associated molecular patterns (DAMPs) are proteins released by dying renal cells that play a role in activating and recruiting inflammatory cells and exacerbating renal injury. Renal fibrosis is associated with DAMP-mediated inflammation. Therefore, we hypothesized that secreted extracellular NF-E2 acts as a DAMP and promotes neutrophil activation, recruitment, survival and promotes renal fibrosis. Neutrophils were exposed to control and Acr-sups and cell lysates were immunoblotted with appropriate antisera.

Acr-sups stimulated pro-survival ERK phosphorylation (pERK) and promoted neutrophil survival by inhibiting cleavage and activation of pro-apoptotic protein, caspase-3. Acr-sups also stimulated neutrophil actin polymerization and chemotaxis. To determine if NF-E2 mediates these effects, Acr-sups were subjected to anti-NF-E2 immunoprecipitation. Depletion of NF-E2 from these supernatants inhibited pERK, stimulated pro-apoptotic pP38MAPK and enhanced caspase-3 cleavage. Recombinant NF-E2 stimulated neutrophil pERK, actin polymerization, chemotaxis and survival. Anti-NF-E2 antibody therapy may serve as a therapeutic option to reduce inflammation and ameliorate acrolein-induced renal toxicity.

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Math : Science : Technology
Regional Finalist

Name: Anirudh Suresh
High School: St. John's School
Mentor: Dr. Richard Wolf
Project Title: *Modeling Sharp Jumps in Flux Tube Entropy in the Earth's Magnetosphere*

This study seeks to understand the quiet auroral arcs that appear in the evening sky at high latitudes. Due to the lack of methods that reliably predict these arcs' configurations, this research aimed to calculate the plasma and magnetic signatures in cases of arc-forming and non-arc-forming jumps in plasma parameters through a novel computational model based on integration of differential equations. The model computes the magnetic field for various computer-simulation experimental scenarios by calculating the position, pressure, and magnetic field strength at points along each magnetic field line. Tests were performed to check that the equations were solved correctly. The model predicts that arc-forming and non-arc-forming jumps imply a sharp decrease in equatorial field strength in the plasma sheet region of the magnetosphere. A planned future study aims to analyze magnetospheric spacecraft data to search for the kinds of signatures this model predicts; if it successfully locates those signatures, it will have confirmed the driving force behind auroral arc formation. Another direction for follow-up research is the study of the association between arc-forming or non-arc-forming jumps and magnetsopheric substorms, electromagnetic and particle disturbances in the plasma sheet and ionosphere that can disrupt spacecraft operations and damage power systems on Earth.

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Math : Science : Technology
Regional Finalist

Names: David Xiang, Eric Li & Amber Lu
High Schools: Westwood High School, Clements High School & Texas Academy Of Mathematics And Science
Mentor: Dr. Lucas Rusnak
Project Title: *Signed Path Matrices and Oriented Hypergraphic Generalizations*

Every hypergraph can be represented by some matrices. By studying these matrices, we solve several problems in data structure analysis and provide combinatorial interpretations of these re-sults. Previously, a path counting theorem was known for k-regular graphs. In this paper we generalize and extend the theorem to count paths in all oriented hypergraphs, and consequently show its applicability for both signed and unsigned graphs. We explore the bipartite model of a hypergraph and study the relationships between the adjacency, incidence, and Laplacian matri-ces of the aforementioned graphs. In the process we show the ubiquity of the square root of the Laplacian matrix, and use the combinatorial interpretation of this result to introduce the idea of a fractional walk. We also analyze and provide an interpretation of the matrix-tree theorem in the context of hypergraphs, and explore the methods of counting trees in signed graphs. Our path counting theorems allow efficient computation of the minimum number of connections needed to guarantee a majority of positive connections between nodes. This gives our results immediate applications in many fast growing fields such as social networking, mobile computing, and data analysis. Furthermore, it has applications in structural design, such as in VLSI systems and neu-rological modeling, as hypergraphs are ideal for modeling large, complex technological and social systems where multi-relationships are prevalent.

Siemens Competition
Math : Science : Technology
Regional Finalist

Name: Jovan Zhang
High School: Los Alamos High School
Mentor: Dr. Duan Zhang
Project Title: *Modeling Gas Flow in Hydraulically Fractured Shale*

Currently, predicting the behavior of a shale gas well has proved challenging --- the long term predictions are much lower than field data has shown. As a consequence, many wells are abandoned or closed prematurely due to the inaccuracy of such predictions. This highlights the necessity of an accurate model which could ultimately decide the fate of a shale well. In this project, we devised a simple rock damage model to better predict the long-term production of hydraulically fractured shale wells, combined this damage model with a nonlinear pressure diffusion equation derived from the law of mass conservation, Darcy's law, and the Peng-Robinson equation of state. The effect of evolving permeability is considered for the first time to predict the production of hydraulically fractured shale gas wells. We then numerically solved the equation, tested convergence of the numerical schemes, and compared the results to field data available in the literature. Good agreements between production field data and the numerical calculation are observed.

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Names: Shoshana Zhang & Colleen Dai
High School: Texas Academy Of Mathematics And Science
Mentor: Dr. William Acree Jr., University of North Texas
Project Title: *A Novel Prediction of Alternatives for Solvents Toxic to Human and Environmental Health through Computational and Statistical Modeling*

Through our research, we formulated an economical method for finding alternatives to widely used human carcinogens and toxins. Annually, two million tons of toxic solvents are released by industries into the environment, causing on average 88 worker deaths every week in the United States alone [1]. To curtail human exposure to these hazards, the discovery of alternatives to harmful solvents is essential, but there is no cost-effective and time-efficient method to determine replacements for specific carcinogens [2]. Our research uses a linear free-energy model and statistical analysis to discover replacements for carcinogenic industrial solvents such as carbon tetrachloride and environmentally hazardous compounds like benzene.

To identify alternative solvents to ten toxic solvents, we calculated the solubilizing properties of 155 solvents through chemical testing, absorbance analysis, and statistical calculations. We then compared quantified properties of all of the solvents to reveal property similarities. To ensure accuracy, we further confirmed the proximity of similar solvents by using the distance formula and Principal Components Analysis.

Our novel research process enabled us to discover effective and safe alternative solvents for various toxins and human carcinogens. This process sets the stage for selecting friendly solvents and eliminating harmful solvents in industrial practices.