Siemens Competition
Math : Science : Technology
Regional Finalist

Names: Garyk Brixi, Gordan Brixi
High Schools: Churchill High School, Saddlebrook Preparatory School
Mentor: Virginia Brown
Project Title: Investigating Alternative Cost Effective Relief Foods

Current malnutrition relief foods are unnecessarily costly and inadequate in their content of choline and omega-3 fatty acids. We investigate alternative ingredients to reduce the cost and enhance the nutritional benefits of relief foods. We develop a novel modular system to facilitate the localization of relief food production. Compared to the existing relief food formulae, our proposed formulae provide the required nutrient and caloric value at a significantly lower cost -- partly through replacing peanuts with a combination of soybean, maize and vegetable oil, and using whey instead of milk powder. Furthermore, our proposed formulae offer improved nutrition through soybeans and through choline and omega-3 supplements. Our formulae prioritize water efficient crops grown in proximity to malnourished populations to allow local production. Finally, to further facilitate localization, our proposed modular approach allows exchanging ingredients within nutritional categories, modifying the amount of each ingredient and micronutrient mix to meet the nutritional goal for specific type of malnutrition. This gives greater flexibility to relief food production. Lowering the cost, improving nutritional value, and facilitating local production of relief food will help alleviate hunger and malnutrition in developing countries.

Siemens Competition
Math : Science : Technology
Regional Finalist

Names: Jang Hun Choi, Matthew Li, Elaine Moon
High School: Jericho High School, Horace Mann School, Peddie School
Mentor: Dan Ismailescu
Project Title: A New Lower Bound for the Fractional Chromatic Number of the Plane

A unit-distance graph is a graph that can be drawn in the plane so that every pair of adjacent vertices corresponds to points that are unit-distance apart. A coloring of the vertices of a graph is called proper if no two adjacent vertices are assigned the same color; the minimum number of colors needed for a proper coloring is the chromatic number of the graph.

The main unsolved problem is how large the chromatic number of a unit-distance graph can be. It is known that certain unit-distance graphs require 4 colors, while 7 colors are sufficient for any unit-distance graph.

In a fractional coloring of a graph, we assign to each independent set a nonnegative weight, such that each vertex appears in independent sets with weights summing to at least 1. The fractional chromatic number of the graph is the minimum sum of weights on the independent sets that allows such a coloring. This definition comes from solving the linear relaxation of the integer programming formulation of chromatic number.

In this paper we investigate the following problem: how large can the fractional chromatic number of a unit-distance graph be? Improvements of the (easy to prove) lower bound of 3.5 were found by Mahan, and Fisher and Ullman. The current record is due to Cranston and Rabern, who recently proved a lower bound of 76/21 = 3.6190… for this quantity. We improve their result by constructing a 40-vertex unit-distance graph with fractional chromatic number 11/3 = 3:6666….

Siemens Competition
Math : Science : Technology
Regional Finalist

Names: Jacy Fang
High School: Bergen County Academies
Mentor: Dr. Michel Sadelain
Project Title: The Living Drug: A Novel Method of Inducing Stem-Like Memory T Cells from Antigen-Experienced Cells for CAR-T Immunotherapy

Stem memory T cells (T_{SCM}) are T cells carrying stem-like properties, which can give rise to other memory and effector T cells. Given their proliferative, self-renewal, long-living, anti-tumor characteristics, these T_{SCM} are highly desirable in adoptive immunotherapy, especially with Chimeric Antigen Receptor (CAR) technology. However, procedures to specifically target this subset remain elusive. While there were studies to induce T_{SCM} from stem cells or naive precursors, there has been no report of regenerating T_{SCM} from other antigen-experienced memory T cells.

A close study of the factors in the hematopoietic microenvironment indicates that they may be constructive in inducing T_{SCM}. To test this hypothesis, a combination of the cytokine Interleukin-7, anti-IFNγ antibody and OP9 stromal cells were presented during the activation of effector memory T cells. Not only did the total number of cells undergo a 96-fold expansion(**P<0.01), but also a subpopulation of CD45RA+C45RO-CD62L+ CD95+CD8+ human T cells(19%), which closely resemble naturally occurring T_{SCM}, were induced. This novel approach was tested (IL-7/anti-IFNγ control) in both CMVpp65+ and CAR+ T cells. The experiment demonstrated it is possible to reverse the T cell differentiation to generate T_{SCM} directly from antigen-experienced memory T cells *in vitro*. This may have broad application in adoptive immunotherapy.

Siemens Competition
Math : Science : Technology
Regional Finalist

Names: Veda Murthy
High School: Lexington High School
Mentor: Dimitris Samaras, Stony Brook University
Project Title: Towards a More Accurate Convolutional Neural Network (CNN) to Classify Glioma Nuclear Images

We investigate automated classification of glioma nuclear shapes and attributes using Convolutional Neural Networks (CNNs). CNNs are machine learning algorithms that have achieved state-of-the-art results in many image classification tasks. However, traditional CNN training methods have little success when labeled data and positive examples in labeled data are limited, which is common in many medical imaging applications. We propose three methods to improve the performance of a previously-developed CNN. First, we propose a method of reducing the dimensionality of an image while still retaining information from the most important part of it- the image's center containing the nucleus. Second, we prove the addition of distinct image information prior to classification improves classification accuracy. Third, we separate the error functions of the two groups of target classes (nuclear shapes and attributes) so that the prior knowledge of inter-label exclusiveness can be incorporated into CNN training. On a dataset of 2078 automatically segmented nuclear images, the three proposed methods in combination reduce the error rate of glioma nuclear attribute and shape classification by 22.54% and 16.83% respectively compared to the existing state-of-the-art method on the same dataset.

Siemens Competition
Math : Science : Technology
Regional 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
Regional 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
Regional Finalist

Names: Nishita Sinha
High School: Chatham High School
Mentor: Dr. Yelena Naumova, Dr. Lisa Rodenburg, Dr. Craig Phelps
Project Title: Experimental Studies in Developing Safe Sanitation Solutions

Worldwide, 2.4 billion people lack access to in-home toilets, hampering health and development. Cramped living spaces without plumbing make traditional toilets infeasible in poor countries. Significant strides have been made towards economic alternatives. One promising option is a 2-pit composting toilet, 61 of which were installed in a village in India by author's initiative. In this toilet, solid waste is effectively treated through anaerobic composting. Concerns remain regarding the impact of effluent liquid waste on drinking water. The design uses a honeycomb-brick structure surrounded by sand, acting as a Slow-Sand-Filtration (SSF) system to filter liquid effluent. The first objective was to fully characterize this filtration, and initial analysis suggests that SSF alone is indeed insufficient at removing fecal coliform from effluent. Second objective involves identifying economic additives to SSF systems. The efficacy of these potential additives in removing fecal coliform bacteria was tested using table-top prototypes, constructed as plug-flow reactors; heterotrophic plate-count method was used to compare bacterial concentration in simulated human waste before and after treatment. In Phase I, addition of pebbles to SSF was found to be 83% more effective. In Phase II, design constraints for liquid additives were evaluated. In Phase III, a Time Varying Electric Field (TVEF) was employed to increase filter sustainability in conjunctive additional solid slow-release additives. 14 additional toilets with updated filters have since been installed. Experimental data is presented and future steps enumerated.

Siemens Competition
Math : Science : Technology
Regional Finalist

Names: Amir Siraj and Shiva Mudide
High School: Brookline High School and Acton-Boxborough Regional High School
Mentor: Dr. Joseph Hora, Harvard–Smithsonian Center for Astrophysics
Project Title: The Relationship Between Infrared Dark Cloud Mass Distributions and Young Stellar Object Populations

Massive star formation is highly influenced by the properties of infrared dark clouds (IRDCs). Using 8μm IRAC data from the Spitzer Space Telescope, we analyzed key properties of 1265 IRDCs within the Cygnus-X region, including mass, column density distributions, and numbers of associated young stellar objects (YSOs). Using data from our analysis, we gained several insights into the nature of star formation, including a novel finding that low- and high-mass IRDCs are almost equally efficient at forming stars. To corroborate our findings from Cygnus-X, we also calculated photometry, classified YSOs, and analyzed the properties of 5 IRDCs in the unrelated G013.28 region. We concluded that the analysis from our Cygnus-X survey holds true in a disparate region of the Galaxy. For a significantly large sample of clouds, we find that IRDC star formation efficiency is largely independent of both total mass and high-density mass undergoing gravitational collapse. These findings shed light on the nature of early massive star formation and raise noteworthy questions about the evolution and star-formation properties of IRDCs in general.

Siemens Competition
Math : Science : Technology
Regional Finalist

Names: Albert Yue
High School: Phillips Academy
Mentor: Dr. Seo-Young Kwak
Project Title: *Remineralization of Enamel using Leucine-Rich Amelogenin Peptide and Pyrophosphate*

Enamel cannot be regenerated once damaged, as the cells that originally construct the layer are lost upon tooth eruption. In this project, we evaluate the calcium phosphate mineralization with the combination of pyrophosphate (PP_i) and leucine-rich amelogenin peptide (LRAP) on the human enamel. In our studies, the surfaces of enamel specimens were applied with 7 mg/mL LRAP solution and dried, and then submersed in a PP_i-stabilized supersaturated calcium phosphate solution for 18 hours at 37°C. Hydroxyapatite (HA) formation occurred favorably at low amounts (10 µL) of LRAP. In the presence of higher amounts (30 µL) of LRAP, amorphous calcium phosphate mineral layers were observed instead. Overall, LRAP may induce HA to form instead of octacalcium phosphate, which was observed in the absence of LRAP. The mineral layers reached microhardness of 268.1 ± 34.98 (10 µL) and 249.8 ± 23.43 HV (30 µL). These values are up to 20% higher than that of etched enamel, which was 221.7 ± 22.48 HV. While further work is necessary, this work points to another promising direction for a new and more effective method of dental treatment for decayed teeth by regenerating enamel.

Siemens Competition
Math : Science : Technology
Regional Finalist

Names: Yi Zhu, Robert Yang,
High School: Thomas S. Wotton High School, Montgomery Blair High School,
Mentor: Dr. Yongping Yang
Project Title: Systematically Profiling HIV-1 Env Trimer Mutations and Changes in Residue Function and Structural Stability

The HIV-1 envelope (Env) trimer, a protein complex comprised of three glycoprotein 120 subunits and three glycoprotein 41 subunits, is the primary target of HIV neutralizing antibodies and has been the focus of research on immunogen design. While the Env trimer can elicit neutralizing antibodies, its conformational change when the HIV virus invades T-cells greatly reduces its value as an effective vaccine. The objective of our research is to optimize immunogen design by identifying residues important for Env trimer antigenicity and prefusion stability. Based on the binding affinities of various HIV-1 Env trimer mutants to neutralizing and non-neutralizing antibodies, we analyzed each Env residue's antigenicity and structural functionality. Our results demonstrate that residues on the surface of the Env trimer affect antigenicity, whereas residues buried in the Env trimer stabilize its conformation. We also generated a database encapsulating each Env residue's amino acid property, surface localization, antigenicity, and structural function to facilitate the work of other researches by sharing our data. The insights from our results may not only bring us one step further to developing an effective HIV-1 vaccine, but also help researchers discover novel antibodies with greater breadth and potency.