Siemens Competition
Math : Science : Technology
Regional Finalist

Name: Akshaya Annapragada
High School: DeBakey High School for Health Professions
Mentor: Ananth Annapragada, Texas Children's Hospital
Project Title: *The Giant Protein AHNAK Traffics Aptamer Targeted Nanoparticles Specifically Into Oral Cancer Cells*

This study identified a novel targeted drug-delivery platform, with uptake mediated by the protein AHNAK, a receptor appearing on over 80% of known solid tumors.

Effective targeting and liposomal encapsulation can mitigate side-effects and maximize efficacy of RNAi based therapies and chemotherapeutics such as Doxorubicin which require cytosolic delivery.

Targeted delivery requires ligands, such as aptamers. Conventionally, aptamers are screened via SELEX, which selects aptamers for surface delivery, not payload localization.

This study pioneered an original modification to SELEX, Conjugate-SELEX, which screened aptamer-liposome conjugates, enriching those that achieved cytosolic payload localization, and confirmed the viability of these novel targeted nanoparticles.

An aptamer-liposome conjugate for drug-delivery to Oral Cancer, and potentially other cancers expressing AHNAK, was identified. Mass spectrometry identified the protein AHNAK as the uptake mediating surface receptor. Quantitative image analysis demonstrated cytosolic delivery capabilities. Delivery of live siRNA and Doxorubicin was tested. Western blot analysis confirmed silencing, indicating successful siRNA delivery. Cytotoxicity assays were performed, and the aptamer formulation induced greater cell death than the conventional untargeted drug.

This study confirms the potential of aptamer-liposome conjugates identified through the conjugate-SELEX method as a unique platform with wide- ranging applicability and implications for oncological drug- delivery.

Siemens Competition
Math : Science : Technology
Regional Finalist

Names: Daniel Chae, Alan Tan & Sidharth Bommakanti
High Schools: Thomas Jefferson High School of Science and Technology, Irvington High School & Amador Valley High School
Mentor: Adriana Pinkas-Sarafova, Stony Brook University
Project Title: *A Novel Study on the Effect of Surface Topography of 3D Printed Polylactic Acid Scaffolds on Dental Pulp Stem Cell Proliferation and Differentiation in vitro*

In the field of medicine, 3D printers offer a promising approach to the creation of customized dental implants. This study evaluated the extent to which 3D printed devices are equivalent to traditional molded scaffolds, which are already FDA approved products. Polylactic acid (PLA), an effective material for cell scaffolds and one of the most popular filaments used in commercial 3D printers, was used to create the scaffolds. Scanning Electron Microscope (SEM) showed significant differences in surface topography between 3D printed and spuncast (ideal molded) scaffolds. Surprisingly, differences were also observed between scaffolds produced by different 3D printers. When dental pulp stem cells (DPSCs) were plated onto 3D printed and spuncast surfaces, it was found that there were significant differences in attachment, morphology, proliferation, and expression of extracellular matrix proteins, indicating that the cells underwent differentiation. The 3D printers created scaffolds that induced higher levels of differentiation, but maintained similar level of proliferation compared to those of spuncast scaffolds. These findings are of great importance in respect to the applications of 3D printed devices for tissue regeneration.

Siemens Competition
Math : Science : Technology
Regional Finalist

Names: Kelly Cho & Harriet Khang
High School: Thomas Jefferson High School of Science and Technology
Mentor: Ji Hoon Lee, Luminescent MD, LLC
Project Title: *All-In-One Biosensor For The Early Diagnosis And Prognosis Of Breast Cancer*

Using a dual DNA aptamer (CEA aptamer-linker-hemin aptamer) connected through a linker, capable of rapidly binding with carcinoembryonic antigen (CEA) and hemin, we developed a convenient, all-in-one biosensor with 1,1'-oxalyldiimidazole (ODI) chemiluminescence for the rapid quantification of CEA, a breast cancer biomarker. First, we had CEA and hemin competitively bind with the dual DNA aptamer while we incubated this mixture in a detection cell for 30 minutes at room temperature. When the Amplex Red and H2O2 were added into the detection cell after the incubation, the yield of resorufin formed from the reaction between the dual DNA aptamer and the Amplex Red and H2O2 depended on the concentration of HRP-mimicking G-quadruplex DNAzyme produced from the binding interaction between the hemin and the dual DNA aptamer. Then, when we added ODI and H2O2 to the detection cell to produce resorufin, the detection cell emitted a bright red light that was brighter in the absence of CEA than in the presence of CEA. This is because the HRP-mimicking G-quadruplex DNAzyme was competitively produced with the CEA-bound dual DNA aptamer when hemin and CEA were added into the aqueous solution containing the dual DNA aptamer. Thus, the relative CL intensity of the all-in-one biosensor was exponentially decreased with the increase of the CEA concentration in the human serum. The limit of detection of the all-in-one biosensor which operated with excellent accuracy, precision, and reproducibility was as low as 0.71 ng/ml. Finally, the correlation between the all-in-one biosensor and the conventional enzyme-linked immunosorbent assay indicated that the all-in-one biosensor could be applied as a novel clinical tool for the early diagnosis of breast cancer.

Siemens Competition
Math : Science : Technology
Regional Finalist

Name: Beverly Ge
High School: F. W. Buchholz High School
Mentor: Peng Jiang, University of Florida
Project Title: *Novel Chromogenic Vapor Sensors Enabled by Shape Memory Polymers*

The detection of chemical vapors is a significant issue in environmental monitoring, disease detection and national security, yet no inexpensive, user-friendly, multipurpose sensor is currently available. The purpose of this project is to develop chromogenic vapor sensors using a new type of vapor-responsive shape memory polymer (SMP) and to further the basic understanding of these SMPs.

Experiments were conducted using macroporous SMPs fabricated through 1) the self-assembly of multilayer silica colloidal crystals; 2) the introduction of a monomer mixture to fill up the interstitial gaps; 3) the photopolymerization of the monomers; and 4) the selective removal of the silica templates. The resulting SMP films were exposed to various chemical vapors (acetone, benzene, dichloromethane, hexane, and methanol), and color change was measured by both an optical spectrometer and a smartphone color-analyzing application.

While the spectrometer data do not demonstrate perfect differentiability among the chemicals, preliminary tests with the smartphone application show that the SMPs' vapor-triggered color responses are detectable by smartphones through the colors' unique RGB values. Computer simulations confirmed the experimental results. Finally, a linear relationship was found between the surface tensions of the chemicals and the peak wavelengths, helping to explain the basic mechanisms of these SMPs.

Siemens Competition
Math : Science : Technology
Regional Finalist

Name: Maria Grimmett
High School: Oxbridge Academy of The Palm Beaches
Mentor: Hui Li, Michigan State University
Project Title: *Adsorption of Sulfamethazine from Environmentally Relevant Aqueous Matrices onto Hypercrosslinked Adsorbent MN250†*

Sulfamethazine, a prominent agricultural antibiotic, contaminates groundwater with subsequent ecological toxicity. Remediation methods are not universally effective, necessitating newer techniques. Hypercrosslinked polystyrene adsorbents show promise because of high surface areas, durability, and regenerable properties. Using batch techniques, sulfamethazine adsorption onto Purolite MN250 was evaluated with dissolved humic acid, common groundwater ions, varying pH, and increasing ionic strength. The adsorption capacity of MN250 for sulfamethazine (Qe) was high, ranging between 80.33 at pH 9 and 181.0 mg g-1 in 0.005 M KCl. The capacity with humic acid was 109.3 mg g-1. Qe decreased one-third as the aqueous solution became alkaline, with optimal performance at pH 7 (144.0 mg g-1), because sulfamethazine speciation and MN250's zeta potential vary as a function of pH. Increasing ionic strength initially decreased Qe by 34% by altering the activity coefficient of sulfamethazine and by altering the properties of the electrical double layer, while salting-out increased Qe by 26% at seawater concentration (153.4 mg g-1). Adsorption kinetics appear sufficient for field applications. MN250's high sulfamethazine capacity in environmentally relevant aqueous matrices highlights its potential for groundwater remediation.

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† All statements, data, and figures presented herein have been published in whole, or in part, at:

Competition Entrant. 2015. Adsorption of sulfamethazine from environmentally relevant aqueous matrices onto hypercrosslinked adsorbent MN250. J. Environ. Qual. 44:1183–1192. doi:10.2134/jeq2015.02.0109

Competition Entrant. 2013. Removal of sulfamethazine by hypercrosslinked adsorbents in aquatic systems. J. Environ. Qual. 42:2–9. doi:10.2134/jeq2012.0219

Siemens Competition
Math : Science : Technology
Regional Finalist

Names: Chaeyeon Oh, Yujin Kim
High Schools: Episcopal High School, Stony Brook School
Mentor: Dan Ismailescu, Hofstra University
Project Title: *On The Size Of The Euclidean Sphere Of Influence Graph*

Let V be a set of n points in the plane. For each $x \in V$, let Bx be the closed ball centered at x with radius equal to the distance from x to the nearest neighbor. We refer to these balls as the spheres of influence of the set V . The closed sphere of influence graph on V is defined as the undirected graph where {x, y} is an edge if and only if the Bx and By have nonempty intersection.

Sphere of influence graphs were introduced by Toussaint in 1980. They have applications in fields such as low-level computer vision, cluster analysis, pattern recognition, geographic information systems, and others.

It has been known that a closed sphere of influence graph has a linear number of edges. Bateman and Erd˝os proved an upper bound of 18n; this was successively improved to 17.5n by Michael and Quint, and to 15n by Soss.

From the other direction, it is easy to see that the closed sphere of influence graph whose vertex set is a the hexagonal lattice has 9n edges in total.

In this paper we show that no sphere of influence graph of n vertices can have more than 14.5n edges. The proof combines the technique of Bateman and Erd˝os of fitting points into annuli with several ideas of Soss.

Siemens Competition
Math : Science : Technology
Regional Finalist

Names: Christina Oh & Edward Oh
High Schools: Thomas Jefferson High School of Science and Technology & South County High School
Mentor: Christopher Spillmann, Naval Research Laboratory
Project Title: *Investigating Interfacial Crosslinking to Combat Hard Foulants*

Two novel collection methods using slab gels and glass microspheres have been successfully established for studying cementing processes occurring in the barnacle. These experimental techniques effectively sampled materials in the cement interface where previous collection methods failed to access without compromising enzyme activity. Colorimetric assays on this adhesive detected evidence that polyphenol oxidase (PPO) activities – laccase and Tyrosinase – were present and localized in the adhesion interface. Traditional native PAGE gels were also conducted on the main body organs of the barnacle and showed no presence of these PPOs. The combined results from these observations possibly provides crucial clues for understanding the glue mechanism of the barnacle, directing further research on the role of PPOs in barnacle cross linking.

Siemens Competition
Math : Science : Technology
Regional Finalist

Name: Shreya Patel
High School: North Carolina School of Science and Mathematics
Mentor: Thomas Schmedake, University of North Carolina at Charlotte
Project Title: *Development of a Functional Electrochromic Device and Syntheses of [Si(tolylterpy)2](PF6)4 and [Si(bpy)3](PF6)4*

Every year, U.S. citizens spend most of their energy bill on heating and cooling. This high demand for energy is associated with increased global temperatures due to increased production of greenhouse gases. The electrochromic window is an emerging appliance that is an effective way to decrease energy consumption. Electrochromic windows have been synthesized using transition metal-based compounds, however, these metals are rare and expensive. Some compounds, known as viologens, exhibit electrochromic properties, but are extremely toxic. The goal of this project was to create an electrochromic device that was inexpensive, earth-abundant, and safe for humans using hexacoordinate polypyridylsilicon complexes. The existing compound, [Si(bpy)3](PF6)4 , and the novel compound, [Si(tolylterpy)2](PF6)4, were synthesized in this experiment by following and modifying existing procedures. The spectroelectrochemical properties of these compounds were characterized after performing redox reactions to the compounds in a degassed spectroelectrochemical cell. The silicon complex, [Si(bpy)3](PF6)4, was used to develop the first functional electrochromic device from a polypyridylsilicon(IV) complex. Experimentation continues, but the data gathered shows that hexacoordinate polypyridylsilicon complexes exhibit electrochromic activity when undergoing low-voltage redox reactions, and thereby can be used in electrochromic devices.

Siemens Competition
Math : Science : Technology
Regional Finalist

Names: Vamsi Varanasi & Vinit Ranjan
High Schools: Enloe High School & North Carolina School of Science and Mathematics
Mentor: Fanxing Li, North Carolina State University
Project Title: *MgO-Promoted NiAl2O4 Spinel Nanostructures for Efficient Reforming of Biogas*

The world's ever-increasing energy demands necessitate sustainable production of carbonaceous fuels. Biogas (a CH4/CO2 mixture) often released from landfills, offers a vast, untapped fuel reservoir. Dry reformation of methane (DRM) is a highly attractive mechanism to convert biogas into syngas (an H2/CO mixture), a valuable fuel precursor. However, DRM requires high reaction temperatures and is prone to a plethora of side reactions that decrease catalytic conversion. In this study, we present a NiAl2O4 spinel nanostructure promoted with MgO that demonstrates high catalytic activity. We modulated the Ni:Al ratio in the spinels to examine the role of Ni in the reaction process. Our findings indicate that a 0.125:1 ratio of Ni:Al is ideal for DRM catalysis, exhibiting 67% less deactivation over a 10 h period than a reference Ni@Al2O3 core-shell catalyst sample. The resultant syngas have an H2/CO ratio 25% closer to the desired proportion of 1 than syngas produced by the reference, increasing its applicability in fuel synthesis. Additionally, coke formation is significantly reduced and particle sintering is completely suppressed by the MgO. Furthermore, the NiAl2O4 spinel is shown to catalyze DRM efficiently at 100 oC less than the typical reaction temperature, which increases the commercial viability of DRM.

Siemens Competition
Math : Science : Technology
Regional Finalist

Name: Michael You
High School: Thomas Jefferson High School of Science and Technology
Mentor: Xuemei Chen, United States Patent & Trademark Office
Project Title: *Two-degree-of-freedom Bubble Oscillations in Elastic Vessels and its Application in Sonar-induced Marine Mammal Injuries*

Mass strandings of whales and other cetaceans near US Navy sonar operations have made headline news in the last two decades. The reason of these strandings remains controversial among scientists. Here it is proposed that bubble resonance plays an important role in vascular tissue damage, in particular in small blood vessels and capillaries. A theoretical model is built to simulate bubble oscillations in blood vessels. By considering vessel compliance, a two-degree-of-freedom system is developed to simulate coupled oscillations in both axial and radial directions. Numerical simulations are carried out to test the effects of variable stiffness on the oscillations in the two directions. It is found that the vessel compliance has a significant influence on the bubble resonance frequency and amplitude. The bubble oscillations induced by the sonar could lead to resonance and possible collapse of these bubbles, which would damage blood vessel walls and surrounding tissues. The proposed model could more accurately predict the resonance frequency and provides a guide for selecting a safe sonar operation frequency and strength in order to reduce sonar-related injuries to marine mammals.