

# Siemens Competition

## Math : Science : Technology

### Regional Finalist

**Names:** Sarah Adamo and Susell Contreras

**High School:** Smithtown High School West and Brentwood High School

**Mentor:** Dr. Joanne Figueiredo

**Project Title:** Using *Nematostella vectensis* to spotlight the ancient roots of Nicotinic Cholinergic Neurotransmission

Nicotinic acetylcholine receptors (nAChrs) play important role in both peripheral and central nervous system function. While much is known about nicotinic cholinergic neurotransmission in bilateria, relatively little is understood in non-bilaterian animals. This study investigates the evolution and function of nAChrs in the model organism *Nematostella vectensis*. *Nematostella vectensis* has become an important model system for studying the nervous system, however there are currently no behavioral correlates for any type of neurochemical stimulation. In the present study we investigated if peristalsis was coupled to nicotinic cholinergic stimulation in *N. vectensis*. We present novel findings, and data supports the hypothesis that peristalsis is directly correlated to nicotinic cholinergic receptor activation and that this is calcium dependent. Our evidence is that 1) there is a robust, consistent and highly significant increase in number of peristaltic waves in the presence of the agonist nicotine; 2) The effect of nicotine is dose dependent; 3) The ability of the animals to have peristaltic waves both under control conditions and in the presence of nicotine is highly calcium dependent; and 4) *N. vectensis* express transcripts that code for proteins that are homologous to nAChrs from mammalian systems.

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### Regional 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.

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### Regional 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.

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### Regional Finalist

**Names:** Hyunsun (Heidi) Kim, Seung Hwan An, and Joo Sung Yi

**High School:** Trinity School, Taft School, Taft School

**Mentor:** Dan Ismailescu

**Project Title:** On the Polychromatic Number of the Plane

#### ON THE POLYCHROMATIC NUMBER OF THE PLANE

**ABSTRACT.** An  $n$ -coloring of the plane is a function that assigns to each point of the Euclidean plane  $\mathbb{E}^2$  one color from a list of  $n$  colors. We say that a set  $S \subset \mathbb{E}^2$  fails to realize distance  $d$  if no two points in  $S$  are at distance exactly  $d$  from each other.

An  $n$ -coloring is of type  $(d_1, d_2, \dots, d_n)$  if color  $i$  fails to realize distance  $d_i$  for every  $1 \leq i \leq n$ .

The *chromatic number of the plane*,  $\chi(\mathbb{E}^2)$ , is the minimum value of  $n$  for which an  $n$ -coloring of type  $(1, 1, \dots, 1)$  exists. It is easy to prove that  $\chi(\mathbb{E}^2)$  is between 4 and 7, but no better bounds are known although the problem is more than 60 years old.

The *polychromatic number of the plane*,  $\chi_p(\mathbb{E}^2)$ , is the minimum value of  $n$  for which an  $n$ -coloring of type  $(d_1, d_2, \dots, d_n)$  exists for some values of  $d_1, d_2, \dots, d_n$ , not necessarily all equal to each other.

Clearly,  $\chi_p(\mathbb{E}^2) \leq \chi(\mathbb{E}^2)$ , and it is known that  $4 \leq \chi_p(\mathbb{E}^2) \leq 6$ .

In this paper we present two new 6-colorings.

In the first coloring, each of the first three colors avoids distance 1, while each of the remaining three colors fails to realize any distance in the interval  $[2/3, 7/9]$ .

In the second coloring, each of the first four colors avoids distance 1, while each of the last two colors fails to realize any distance in the interval  $[5/9, 4/5]$ . This answers a question of Woodall.

In the second part of the paper we construct a 7-coloring of the plane, each of the first six colors failing to realize distance 1, and the seventh color occupying a fraction  $1 : 6426.69$  of the plane. This is a slight improvement of a result of Pritikin.

# Siemens Competition

## Math : Science : Technology

### Regional Finalist

**Names:** Stephen Lee and Fred Chu

**High School:** Manhasset High School

**Mentor:** Ms. Alison Huenger

**Project Title:** Optimizing Dye-Sensitized Solar Cells through the Co-Adsorption and Tri-Adsorption of Natural Dyes and the Application of a Conductive Copper Infrastructure and a Novel Method of Validation

The use of solar energy, particularly dye-sensitized solar cells (DSSCs), can be a possible solution to the growing global energy crisis. The DSSCs in this study were constructed using FTO glass slides annealed with TiO<sub>2</sub>, through the use of a hot plate(400°C). Slides were exposed to their corresponding dye mixtures overnight to adsorb the anthocyanin, betacyanin, and/or chlorophyll in mono-adsorption, co-adsorption, or tri-adsorption. These structures were then compared to tandem cells, basically two DSSCs stacked on top of each other. Cells were then constructed, and tested for power outputs using a multimeter. For each group, there was one with a copper coil, and one without, to facilitate electron transport within the cell. All data collected was analyzed using a one-way ANOVA followed by a post-Hoc Scheffe ( $p < 0.05$ ). Statistical significance was found between the tri-adsorption copper group, the control, tandem, and all of the no copper groups, where the copper group achieved a higher efficiency due to an increase in amperage output. In electrotaxis, the copper group was found to be the only group able to attract worms to the anode like in literature. This suggests that the implementation of tri-adsorption and copper wires to the basic DSSC design improves efficiency.

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## Math : Science : Technology

### Regional Finalist

**Names:** Dylan Li

**High School:** Hunter College High School

**Mentor:** Li Qiang

**Project Title:** Designing and Testing a Compound Targeting the Divergent Roles of Adipose PPAR $\gamma$  in Regulating Metabolic Homeostasis

The obesity pandemic exacerbates the risk for deadly comorbidities including Type II Diabetes (T2DM). Current obesity and T2DM therapeutics are nonviable because they are ineffective or toxic. One class of antidiabetic drugs called TZDs improves insulin-sensitivity by augmenting the activity of PPAR $\gamma$ , a transcription factor regulating fat function and metabolic homeostasis. However, TZDs cause side effects ranging from weight gain to osteoporosis. This study reevaluated PPAR $\gamma$  as both an obesity and T2DM TZD drug target by exploring distinctions between PPAR $\gamma$ 's two isoforms, PPAR $\gamma$ 1 and PPAR $\gamma$ 2. Oil-Red-O lipid staining and QPCR of primary adipocytes and human fat revealed PPAR $\gamma$ 2 potentially induces lipid synthesis and TZDs' side effects. Conversely, these experiments showed PPAR $\gamma$ 1 upregulates beneficial hormones that reduce adiposity. Thus, limiting PPAR $\gamma$ 2 function may alleviate the pathogenesis of obesity and TZDs' poor therapeutic viability. Subsequently, a drug was designed to partially inhibit PPAR $\gamma$ 2 activity without interfering with PPAR $\gamma$ 1. Oil-Red-O staining and QPCR of adipocytes treated with the drug revealed the drug reduced PPAR $\gamma$ 2 activity but minimally affected PPAR $\gamma$ 1 activity. This study, therefore, distinguishes PPAR $\gamma$ 's isoforms and leads to a therapeutic design limiting PPAR $\gamma$ 2 function while maintaining PPAR $\gamma$ 1 activity. Ultimately, this novel drug may prove effective in improving TZD treatments and combating obesity.

**Please upload your abstract, in this template, by Monday, October 31, 2016 at noon EST.**

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## Math : Science : Technology

### Regional Finalist

**Names:** Sharon Lin

**High School:** Stuyvesant High School

**Mentor:** Jason Econome

**Project Title:** A Novel Multiparameter Optical Sensor Using CMOS Imaging and Remote Neural Networks for Microbial Analysis

Though real-time microbial analysis systems may be accurate in detailing qualitative information on water quality, the maintenance required provides an obstacle for developing communities at risk for bacterial illnesses. By creating a semi-automated optical sensor that utilizes a complementary metal-oxide-semiconductor (CMOS) camera to digitally capture particles from a containment cell containing directly sourced water, photographs can be processed and wirelessly transmitted to a remote server. Through a deep neural network software, 50 parameters can be determined to categorize particles and their frequency of appearance in water sources. Comparing across libraries of images can accurately allow the program to predict bacterial formations, relying on a filtered contrast for edge detection and other factors. Determining bacterial and abiotic particle forms persisting in potable water allows for early detection of potential outbreaks and issues in quality, resulting in more effective preventative measures and greater security for at-risk communities.

# Siemens Competition

## Math : Science : Technology

### Regional Finalist

**Names:** Erika Nemeth

**High School:** Smithtown High School East

**Mentor:** Dr. Peter Brink

**Project Title:** Cell-Based Delivery of Gene-Silencing Products Via Gap Junction Channels

It is known that microRNAs (miRNA) have tumor suppressive effects in an array of human cancers, are highly specific, and are able to be passed through intercellular gap junction channels. However, an effective delivery system for such gene-silencing products has yet to be optimized for therapeutic applications. This study investigated the regulatory effects of miRNA in human prostate cancer cells (PC3) and the potential of a cell-based delivery system of miRNA from donor cell to recipient cell. Normal adult human bone marrow-derived mesenchymal stem cells (hMSC) were selected as donor cells because they are stable, selective, and do not illicit an immune response. Results showed that microRNA-16 is a significant regulator of PC3 cell growth in monoculture, and that hMSCs are able to deliver microRNA-16 to recipient PC3 cells with the regulatory effects preserved. Additionally, proof of concept of this cell-based delivery system was successfully demonstrated *in vivo*. This study presents a preliminary model for therapeutic applications of a cell-based miRNA delivery system in cancer.

# Siemens Competition

## Math : Science : Technology

### Regional Finalist

**Names:** Eric Pun and Nikhil Saggi

**High School:** Syosset High School

**Mentor:** Ms. O'Shea

**Project Title:** Increasing Concrete Durability in Extreme Temperatures with the Use of Sodium Silicate

Concrete, a ubiquitous building material, develops different mechanical responses including water permeability and uniaxial compressive strength when exposed to extreme temperatures. Cement was surface coated with sodium silicate grade N in three curation climates to determine the effectiveness of silicate treatment in varying ambient temperatures. Samples were subjected to compression testing and water absorption to assess changes in durability and strength. Cement samples treated with silicates initially absorbed about the same amount of water as the control with a difference of 0.5% to 1% increase in density for both the 21°C and 40°C curation temperatures. For cold samples however, silicate treatment had detrimental effects as samples had a 5.1% higher increase in density than the control. For room temperature samples, the silicate treatment proved effective by increasing the overall compressive strength among all failures. However, while warm temperature, sodium silicate treated samples showed little change in strength from the control, cold temperature, sodium silicate treated samples performed poorer than the control. With sodium silicate, concrete can resist the negative impacts of a warm curation climate, but the harmful effects of a cold climate are not alleviated.

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## Math : Science : Technology

### Regional Finalist

**Names:** Nestor Tkachenko

**High School:** Ward Melville High School

**Mentor:** Prof. Sergey Suchalkin

**Project Title:** Can Cars Fly? Eddy Current Magnetic Levitation as Viable Technology

We explore the potential of Eddy current levitation through a combination of theoretical calculations and two types of experiments. It occurs when AC runs through a coil placed above a non-magnetic conducting surface (e.g. aluminum or copper). Our main focus is the power efficiency measured by the ratio of the supplied power to the lift force (power-to-weight ratio, PWR). We distinguished between two contributions to the PWR; internal, associated with power loss within the coil, and external, due to power loss in the conducting plate. Theoretically we expect the internal PWR to be inversely proportional to the thickness of the coil, and that a flat coil has a significantly better power efficiency than a toroidal one of the same thickness. By comparing experimental data from direct observation coil and measurement of inductance and effective resistance of the coils with the theoretical predictions, we concluded that the flat coil is in fact much more efficient than a toroidal one, and its PWR can be substantially decreased by increasing its linear dimensions. The predicted ideal PWR compared favorably with that of existing modes of transportation. This led us to conclude that Eddy current levitation is a viable technology with high commercial potential.