

The Hen Hud Hub

Science Research Newsletter

Special points of interest:

- Cognitive Psychology
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- Environmental science
- Educational Research
- Biology and Medicine
- Genetics
- Engineering

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Hendrick Hudson High School
2166 Albany Post Road, Montrose, NY 10548.

Achievements of our Science Research Students, by Dr. C. Rogers

Congratulations to all of the students who have worked so hard this year and competed.

Ben Toll received an American Gastroenterology Association Grant for his upcoming summer work with Dr. Higgins at the University of Michigan. He is one of ten high school students in the country to be awarded this significant grant. He will be eligible to submit his research abstract in a competition to present at the AGA annual meeting next year in California.

Naimah Hakim competed at the Westchester Putnam Rockland Junior Science and Humanities symposium in February and was awarded First Prize in the Behavior category. She placed third in the Behavior Category at WESEF (Westchester Engineering and Science Fair) as well.

Shannon Kenny was awarded the Patriot Risk Management Group Award for Exceptional Behavioral Project at WESEF in March.

Tiffany Porras was invited by Dr. Teresa Wood to attend the 5th International Congress of the GRS and IGF Society. Some of the research she worked on last summer was presented in a poster by Lauren Rota on this occasion. It was a great opportunity for Tiffany to be immersed in the field, attend symposiums on topics related to her research and be exposed to professional presentations by scientists from all around the world.

Last June, Cassandra Rogers placed Second in the Biology II category and Tiffany Porras placed Third in the Medicine

category at the White Plains Invitational for Sophomores.

Shivane Shah is continuing her fascinating research on the Miraculin fruit, conducting her taste perception experiments in the high school.

Alex Alves will be returning to the Atlantis Marine World Aquarium this summer to continue his study on the preferred habitat of tropical fish.

Alexis Mangual has joined the program with an interesting project on hydrogen fuel cells.

We are looking forward to a great upcoming year with a very talented group of students competing in 2012.

Tracking Synesthetic Tendencies in Normal Cross-Modal Sensory Perception, Naimah Hakim. (Intel paper excerpt)

“Imagine a world in which the number “2” is pink, the word “computer” tastes of jelly-beans, and “F#” has a conical shape” (Ward & Mattingley, 2006). For people living with synaesthesia, these seemingly fantastical responses to our world become genuine perceptual realities. Deriving

from the Greek words “syn” for “union” and “aesthesia” for “sensation,” the word synaesthesia literally means a union of the senses (Asher, et al., 2006).

Francis Galton is credited as the first person to coherently document synaesthesia, noting

that the condition tended to run in families—the earliest indication that synaesthesia may have a genetic basis (1880). However, for nearly a century, synaesthetic allegations were often dismissed as “romantic neurology” with no real scientific base (Humphrey 1990). Historical-

Senior Papers

Tracking Synesthetic Tendencies (cont.)

ly, others have deemed that synaesthetes are simply “crazy” or “acid junkies” (reported by Ramachandran & Hubbard 2001). While there are reports of synaesthesia arising during and after a hallucinogenic high (Grossenbacher & Lovelace, 2001), these hypotheses do not account for people that have experienced synaesthesia as a consistent and automatic aspect of their normal perception, often since early childhood (Ramachandran & Hubbard 2001; Baron-Cohen et al, 1993). Consequently, much research in behavior and neuroscience has aimed to prove synaesthesia’s perceptual legitimacy. Recent studies have used automaticity tests (e.g. Baron-Cohen et al. 1993) and consistency tests (e.g. Mills et al. 1999) to successfully distinguish synaesthetes from non-synaesthetic control groups. Additional studies employing Stroop interference and perceptual grouping tasks (Ramachandran & Hubbard 2001) have also indicated that synaesthesia is indeed a genuine sensory phenomenon.

Current findings do not only indicate that synaesthesia is a genuine perceptual condition, but also demonstrate that synaesthesia comes in all shapes and colors—quite literally speaking. Defined as a condition in which the stimulation of one sensory modality triggers an automatic and involuntary sensation in another modality, synaesthesia may result in cases of “colored hearing,” but can also manifest as “tactile taste” (Nunn et

al, 2002). Synaesthesia is also known to impact a wide variety of psychophysical domains, resulting in synaesthetics triggered by emotional, musical, or chrono-spatial stimuli. Although, the visual or vivid synaesthetics, particularly linguistic/grapheme-color synaesthesia (number-color), seem to be the most widespread and researched variations of synaesthetics.

Variability continues even within a specialized branch of synaesthesia. Aforementioned grapheme-color synaesthetes experience colors when presented with lexical characters such as letters or numbers. However, while the number “2” may elicit green for one synaesthete, the same “2” may elicit orange for another synaesthete. Idiosyncrasies between synaesthetes have made attempts and standardizing experimental techniques on all synaesthetes a challenging task.

However, the phenomenon of individual idiosyncrasies does not mean that research on synaesthesia is limited to case studies. Increased focus is now being placed on understanding how our knowledge of synaesthesia relates to theories of normal cognition (Ward, 2006) and perception. A growing body of research even suggests that synaesthesia and normal cross-modal perception may even share a common underlying neural mechanism (e.g. Cutsforth, 1925). For example, it is known that most people tend to associate high

pitched tones with light colors (Hubbard, 1996; Marks, 1974, 1982, 1987; Melara 1989) and that most people have the ability to produce visual imagery in response to music (e.g. Karwoski & Odbert, 1938). To many, these experiences in normal people echo those of synaesthetes. Thus, these findings raise the question: Is some form of synaesthesia present in all of us?

This study seeks to answer this question by evaluating non-synaesthetic subject responses to auditory and visual stimuli to explore non-synaesthetes perceptual processing parallels synaesthetic processing.

Hypothesis:

The “Kiki/Bouba” test administered by Ramachandran and Hubbard presents subjects with the extremes of two distinct perceptual domains: shape (angular/round) and language (“sharp”/“soft”), and asks subjects to decide whether or not certain attributes of each correlate with each other. Regardless of whether or not subjects were self-identified synaesthetes or not, Ramachandran and Hubbard were able to demonstrate that the majority of subjects (95%) found unconscious appeal in “angular/sharp” and “round/soft” associations, ie. “matching” stimuli that paralleled synaesthetic preferences. These associations of “matching” stimuli, which will henceforth be referred to as congruent stimuli, provide evidence that non-synaesthetes exhibit synaes-



The above pictures are pictures of Ramachandran and Hubbard’s “Kiki” (top) and “Bouba” (bottom). (2001).

Tracking Synesthetic Tendencies (cont.)

thetic tendencies when attending to visual and lexical stimuli. The subject's unwillingness to correlate incongruent stimuli, ie. "unmatching stimuli," further affirms that non-synaesthetes prefer synaesthetically sound stimuli.

The present study aims to use methods of discrimination-tasks to ascertain whether non-synaesthetes demonstrate similar synaesthetic preferences when attending to congruent visual and auditory stimuli. Thus, it is hypothesized that non-synaesthetic subjects will:

demonstrate a faster response when attending to two synaesthetically "congruent" compound- auditory/visual stimuli and, demonstrate a slower response when attending to a compound-auditory/visual stimuli with one or more incongruent" stimuli.

(...)

Conclusions:

The widespread theory that non-synaesthetes and synaesthetes share a common neural mechanism that cross-activates specific areas of the brain is still an area of critical debate within the field of cross-modal sensory perception (cross activation theory) (Ramachandran and Hubbard, 2001). Findings from Experiment 1 and Experiment 2 affirm that non-synaesthetes exhibit synaesthetic preferences that occurs early on in sensory processing, thus suggesting that non-synaesthetes may have similar neural cross-wiring to those with synaesthesia. However,

Experiment 3 results indicate that this preference was influenced by the nature of the designated target-stimuli and the experimental task. This research demonstrates the need for future studies on cross-modal perception to eliminate subject biases that may be induced by the experimental design.

Another fascinating proposal for future research is how synaesthesia may manifest in children. Findings in synaesthetic research today suggest that synaesthesia induces widespread appeal because we are all born with synaesthesia. The reason that some continue to experience synaesthesia into adulthood may be because most people lose their synaesthetic abilities over time as a result of neural pruning (Ramachandran and Hubbard, 2001). Therefore, non-synaesthetes may experience a heightened tendency to respond to congruent stimuli as children and adolescents. Comparing the results of the proposed study to the current study of adults has the potential to reveal new insights on the origins and development of cross-modal perception and synaesthesia.

Implications:

As new technology allows us to localize and trace the neural mechanisms responsible for synaesthetic cross-wiring within the brain, we simultaneously bring humanity closer to solving related phenomena that may have a synaesthetic basis as well. Our "synaesthetic" tendencies to

link sensory modalities with lexical modalities may suggest that the development of language may result from similar neural cross-activation in the brain. Even synaesthetic language, which is prevalent in our everyday speech, (eg. 'sharp taste,' or a 'warm color') may reveal new insights into synaesthesia's role in abstract thinking and metaphor (Ramachandran and Hubbard, 2001).

Additionally, the high proportion of synaesthesia in artists of all talents may be used as evidence that synaesthetic cross-wiring between creative and visual centers in the brain may play a role in the development of fine art. However, this raises another question: What does this suggest about those that possess other talents? It is possible that special abilities in other disciplines such as athletics or academics may stem from specialized cross-wiring that enhances and arouses other brain areas, thus equipping people with certain predisposed neurological advantages. Thus, future studies in synaesthesia may one day reveal how specialized neural networks make us each unique in our abilities.

Research on synaesthesia has come quite far in the last century. Once almost dismissed as a case of "romantic neurology," synaesthesia is now a revolutionary field of study in psychology, behavior, and neuroscience that is adjusting the lens through which we examine perception and cognition in us all.

Mentor:

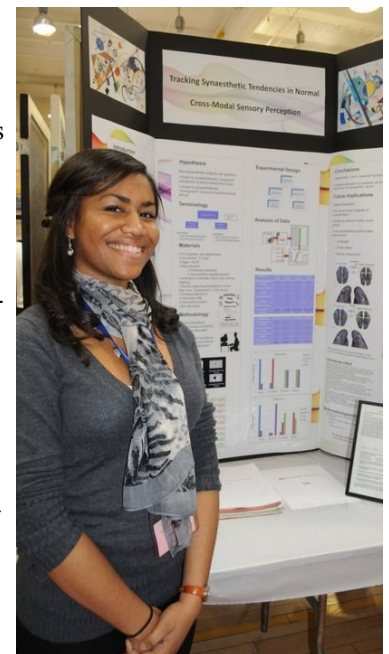
Dr. Lawrence

Marks,

Professor,

Yale School of

Public Health



Naimah Hakim

presenting at

WESEF 2011

Senior Papers

Tracking Synesthetic Tendencies (cont.)

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The Effects of SENTEO Technology on Classroom Performance. Shannon Kenny (Intel Paper excerpt).



Throughout the country, technological devices are being utilized in schools and a significant portion of school budgets is dedicated to the purchase of the latest technological devices, bringing a new feature into the world of education (Bransford 2004). It is predicted that the use of technology in the classroom is only going to accelerate in

years to come, making research on this topic all the more important in order to prepare for the future (Bransford 2004; Lowther 2008). Although there are factors that remain the same, when technology is used in schools, as each technological device is different, it becomes difficult to find information on the benefits and detriments of

each unique device (Zhao 2002). The right technology for a specific classroom's or school's environment needs to be determined by conducting a unique study for that particular location, because some settings require different types of technology than others (Zhao 2002). While there is research that examines the overall use of technology for educational

The Effects of SENTEO Technology on Classroom Performance (cont.)

purposes, individual studies of each device need to be implemented in order to ensure that the device is beneficial for a specific educational area (Zhao 2002).

In the School District in which this study was conducted, a new device, the SENTEO, is being implemented in classrooms. The SENTEO is a hand-held machine connected to an interactive whiteboard that allows students to select answers on a remote after viewing questions. Each student's answers are anonymous to the rest of the class, but the teacher can immediately observe who answered correctly or not.

After a particular lesson, the teacher can go back and analyze the data obtained by the SENTEO to find the strengths and weaknesses of each student, and those of the class as a whole. The SENTEO also allows teachers to get information from the Internet and show it to students, which makes a lesson more interesting and informative. A major benefit of the SENTEO is that it allows immediate feedback to the teacher about the students' progress. The SENTEO also has the potential to assist those with disabilities, for studies have shown that technology can have beneficial affects on the learning process of those with special accommodations (Kelly 2005).

Formal testing of the SENTEO's use can potentially allow for a better-educated decision on the part of the district

when it comes to future budget spending. Dr. Gottlieb, Assistant Superintendent for Curriculum, states, "We support use of the SENTEO because teachers who are trained in Smartboard technology believe the two devices complement each other, and provide both increased engagement for children and immediate feedback for teachers. When teachers research tools and have compelling arguments, I feel it's important to support them as best I can" (Gottlieb, 2009).

Previous studies have concluded that teachers are the defining factor in the success of technology (Zucker 2009; Inan 2009). A teacher's strategies and style, because of technology introduction, has a major impact upon the success of the technology in bringing about academic enhancement (Winter 2010). Therefore, teachers need to use technology as a tool for their own pedagogical advancement in order for it to be affective (Mama, 2010). When they do this, the technology can facilitate higher learning, and allow students to excel to a greater potential (Schmid 2010).

This study will attempt to see whether technology implementation in the classroom, specifically the SENTEO, has a benefit on student achievement.

(...)

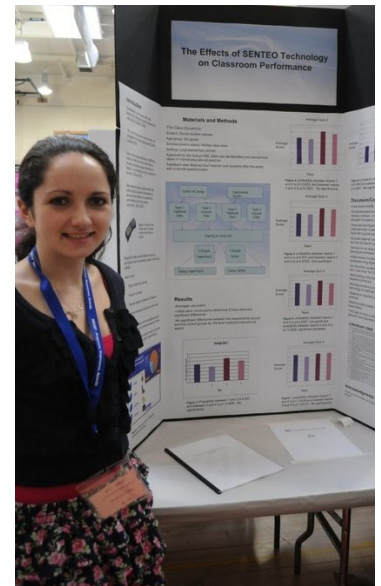
Discussion of the Results

Sources of Error:

There are many reasons why this experiment could have produced inconclusive results: Testing took place at the end of the spring semester, when many students were not giving their full attention to their studies. There were also many assemblies and field trips taking place during experimentation, so time working with the device was scattered and some students were not present through the entire study.

Time and sample size could have created additional errors (Cuban 2001). It is possible that some students merely struggled with the particular topic that was being studied during experimentation and needed more time to understand the material, master it and additional chapters could have been taught. If more time was utilized, then another topic could have been taught to students, and this could have been avoided (Petrina). Another test could have also been distributed, providing more data. With more classes, a greater range of data could have been collected as well, and perhaps clearer trends could be observed (Kozma 2003).

Many people are very excited about the rising "era of technology", where supposedly everyone will be enriched by new devices designed for the betterment of society. But, is this merely a mindset, an idea with no merit, or a legitimate direction in which the world is going? Careful experimentation needs to be carried to show benefits of technology



*Shannon Kenny
Presenting at
WESEF 2011*

Seniors Projects

The Effects of SENTEO Technology on Classroom Performance (cont.)

in instructional efficiency to improve students' scores. All forms of educational technology have been emphasized and marketed much as miracle cures for education, and, as a result, they are expected to automatically improve results in a classroom. But, this idealistic view and such high expectations, which school districts and teachers buy into, keep them from being skeptical.

Conclusion

Various teachers believe that because technology is in their classroom their students will be doing better academically. Technology very often assists in teacher instruction, making it easier for teachers to function. Due to this, teachers assume that their students are functioning on a higher level as well, but that may not be the case. Technology costs a significant amount of money, and when it fails or does not live up to expectations, blame falls hard upon the school district. Many papers which report analyses of the use of technology in the classroom are merely just teachers' commentary, where no field studies are actually conducted and no hard data actually collected. With this lack of controlled studies and numerous external pressures, it is easy to interpret results through the intuitive lens and experience of teachers only. Because technology certainly increases the easiness of certain tasks, such as grading, illustrating of tough concepts, motivating and sparking

the interest of students, it has often become a panacea to remedy all educational problems. However, believing in the complete positive influence of technology on test achievement may not be the best course of action, and teachers, as well as administrators, should question and challenge the new devices that are being brought into the classrooms.

This study was designed to have little possible changes of any parameters between control and experimental groups. As a consequence, teaching strategies were kept controlled, and whatever Ms. W. did with the SENTEO classes, she subsequently did with her other, non-SENTEO classes. It seems that it is the teaching strategies employed, due to technology introduction that facilitated higher learning (Chen 2009, Guzman 2009). By using identical, and more importantly improved, teaching strategies with all of her classes due to the introduction of the technology and the necessity to keep the groups similar, Ms. W. paved the way for all-around academic improvement. For example, both groups took quizzes every day, forcing Ms. W. was able to uncover strengths and weaknesses for all of her classes, and teach them accordingly. The technology in and of itself might not have done anything, except enabling the teacher to teach differently; it was Ms. W. using the information gained from the quizzes that allowed for success

(Baylor 2002). As a result, the SENTEO's use in two classrooms seemed to have limited impact upon academic achievement (Mama 2010), because all four classrooms actually benefitted. However any direct effect of the introduction of the SENTEO was too small to be detected in this study and bigger groups of students, in many classes, would be required to measure an actual effect achievement.

Then why use the SENTEO at all? Why not just adjust teaching strategies to make students do well in school? The fact is many teachers will not change their instruction without the implementation of technology (Baylor 2002). The technology allows teachers to explore new approaches, making innovative instruction simple (Zhao 2002). Ms. W. advanced her own instruction by creating quizzes and polling classes, analyzing the results, and conferencing with her students about their strengths and weaknesses. Without the SENTEO, Ms. W. would not have changed her teaching process (Schmid 2010). Technology makes teaching easier, allowing for more innovation and exploration by the educator (Winter 2010).

But, the SENTEO has flaws; it grouped students under one time frame, treating them as a whole and not individuals while they were taking tests. This could have also contributed to students not doing significantly better while us-

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The Effects of SENTEO Technology on Classroom Performance (cont.)

ing the device. Benefits of using the Senteo, also might be not be detectable by standardized testing on multiple choice tests. They include increased motivation and interest of the students, motivation of the teacher, and better time management, which might have delayed effects of achievement not readily and directly measurable by immediate testing.

This study revealed interesting factors, which are critical in influencing the successful outcome of implementing technology in the classroom. The motivation of the teacher and her eagerness to modify and reflect on her teaching is key to success. Further research needs to be done in regard to this device, but such factors would lead one to believe it is a worthwhile effort to continue to study the effectiveness of this device and how it can enhance learning in the classroom.

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Junior Projects

The Role of Signaling Factors and Effectors of the Notch Pathway on Cell Differentiation of MEC's in Mice, by Tiffany Porras.



Tiffany Porras listening to Lauren Rota present at the International Congress for GRS and IGF Society

Cells that have yet to be specialized are known as stem cells. They are different from mature differentiated cells in that stem cells still have the ability to divide, albeit infrequently (Charafe-Jauffret et al 2008). These “un-specialized” cells divide rarely, compared to cancerous cells, so they always maintain this constant undifferentiated state that allows them to develop into a mature cell in the future (Weissman 2000). Weissman states how these cells have a small subset of stem cells that self-renew for a defined interval, meaning that only certain stem cells self-renew at a certain time, for a specific amount of time. When in adult tissue, stem cells are characterized by their ability of multi-lineage differentiation (Weissman 2000). The earliest types of stem cells are totipotent and give rise to somatic stem and progenitor cells, as well as primitive germline stem cells (Weissman 2000). Adult stem cells begin as pluripotent cells, able to develop into multiple, but not all, cell types (Campbell & Reece 2005). They then turn into multipotent stem cells where they are specialized in a distinct area. Stem cells are capable of constructing non-self-

renewing differentiated progenitors, which then specify into a more restricted differentiating potential and finally become mature cells (Weissman 2000). In order to specialize, stem cells are said to “follow pathways of increasing lineage commitments” (Weissman 2000). With the ability to specialize in various locations of an organism (such as the breast, brain, blood), stem cells can dictate how these cells differentiate in a particular area.

The mammary gland is said to contain stem cells found in the epithelial area of the structure (Smith & Chepko 2001). The mammary gland contains two cell populations once the cells are fully matured (Bouras et al 2008). In one direction, the stem cells pursue the fate of myoepithelial progenitors, which then differentiate into fully grown myoepithelial/basal cells. In the other direction, the stem cells commit to becoming luminal progenitors, which then differentiate into the luminal population that contains both ductal and alveolar cells (Visvader et al 2006). One experiment displayed that in mice, mammary stem cells are found in the basal/myoepithelial area, whereas in vitro cultures have

the progenitors in the luminal cell area (Charafe-Jauffret et al 2008). Both populations contain a distinct amount cells in the self-renewal-like phase. According to Smith and Chepko, if cap cells (multipotent progenitor cells) enter the epithelial cell population near the body of the end bud in the mammary gland, these cells will become part of the luminal cell population. If the cap cells migrate horizontally along the outermost layer of the duct that is in contact with the “fibrous stroma,” then the fate of the cells lies with the myoepithelial population (Smith & Chepko 2001). This is said to be the result of the action of extrinsic factors on the cap cells (Smith & Chepko 2001). Already stated by Weissman, stem cells differentiate into specific cell types through the influence of signaling pathways. Cell specialization may also be said to be the result of gene action that directs the development of the fate of individual cells (Artavanis-Tsakonas 1999). With signaling pathways come signaling factors, which cause any cell of the mammary gland to grow and mature.

Growth hormone (GH) is

The Role of Signaling Factors and Effectors of the Notch Pathway (cont.)

known to be produced by the pituitary gland, which is located right at the base of the hypothalamus in the brain. GH increases protein synthesis in the body, incites the breakdown of fats, and aids in the body's absorption of glucose from the blood (Campbell & Reece 2005). GH also has the important capability to stimulate the liver to secrete insulin-like growth factor I (IGF-I). IGF-I is known to have an effect on the body's growth and development, whether being normal or abnormal. When released from the liver, this growth factor can stimulate the cells in the cartilage, causing the bones of the body to grow (Campbell & Reece 2005). GH and IGF-I have a direct relationship, implicating that when there are high levels of growth hormone, there will be high levels of IGF-I. Therefore, if IGF-I has an effect on cancer, then so must GH. The GH/IGF-I axis has a significant role in the "cancer-cell process," especially in breast cancer, where GH and IGF-I bodily processes influence certain patterns in cancer occurrences that can affect the breast area (Pollak & Schernhammer 2004). The risk of developing cancerous cells increases when there are high levels of IGF-I (Cohen & Clemmons 2000). IGF-I not only increases the possibility of having cancer, but it can additionally play a part in the spreading of a tumor (Cohen & Clemmons 2000).

IGF-I also has a receptor called insulin-like growth factor-I receptor (IGF-IR). IGF-

IR is required for the growth of an organism, as it mediates the action of IGF-I. With IGF-I and IGF-IR are signaling pathways that determine the fate of a cell, including stem cells. One signaling pathway implicated to have an effect on the size of cell population in the breast is the Notch pathway. Notch is known to be involved in normal development of the mammary gland (Charafe-Jauffret et al 2008). Notch signaling in this pathway is a regulator of multiple cellular processes, including stem cell maintenance, cell-fate specification and differentiation (Artavanis-Tsakonas et al 1999). This pathway can act as a regulator of cell survival and cell proliferation (Dontu et al 2004). The induction of Notch signaling also promotes the self-renewal of normal human mammary stem cells (Charafe-Jauffret et al 2008).

To display the implications of Notch signaling on the self-renewal of stem cells, an experiment was performed using normal human mammospheres (Dontu et al 2004). This technique was used to isolate normal human mammary stem and progenitor cells and allow them to self-renew. Thus, cancer risk rises, as Notch can affect lineage-specific differentiation in cells (Dontu et al 2004). Cancer originates in the tissue of stem or progenitor cells possibly through dysregulation of self-renewal pathways, such as Notch (Charafe-Jauffret et al 2008). Abnormal activation of the Notch signaling pathway is most likely an early event in breast cancer

(Charafe-Jauffret et al 2008). Because of irregular expression of certain Notch receptors found in different epithelial abnormalities in the tissue, it has been suggested that Notch may act as a "proto-oncogene" (Dontu et al 2004). This means that Notch has an effect on the progression of cancer in the tissue. Evidence of Notch affecting the irregular division of the cells indicates that mutated forms of the vertebrate Notch1 and Notch4 genes are related to the formation of tumors in mouse mammary glands (Dontu et al 2004). With Notch, there are specific markers that can locate both myoepithelial and luminal cell populations.

Notch signaling can act on multipotent progenitor cells, further assisting the "myoepithelial lineage-specific commitment and proliferation" (Dontu et al 2004). A myoepithelial marker that can locate the basal/myoepithelial cell population is cytokeratin 14 (Smith & Chepko 2001). A luminal cell marker for the luminal population is cytokeratin 18. Another marker of luminal cells is Sca-1, which can help determine whether there is an increase or decrease in luminal cells in the tissue. When relating these two cell populations to Notch, there is the target gene Hey 1, usually being highly expressed in the luminal progenitor cells. Hey genes represent one of the primary targets of the Delta-Notch signaling pathway (Fischer & Gessler 2007). The

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Junior Projects

The Role of Signaling Factors and Effectors of the Notch Pathway (cont.)



Cassandra Rogers and Tiffany Porras receive awards at the White Plains Invitational for Sophomores in June 2010

ligands significant to the Notch pathway are Delta Ligand 1 (DLL1) and Delta Ligand 4 (DLL4). DLL1 is predominately expressed in the myoepithelial/basal cell population while DLL4 is usually expressed with the mammary stem cell-enriched population (Bouras et al 2008).

These markers are important to look at because they can determine whether there is either an increase in the myoepithelial cell population or in the luminal cell population. The goal is to discover that using these markers, which cell population has increased or decreased, and how the activation of the Notch pathway causes changes in the luminal and myo-epithelial populations. Results may indicate the true correlation between the Notch pathway and the development of cancer.

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Possible involvement of SMARCA2 in pathways implicated in schizophrenia, Cassandra Rogers

Schizophrenia is a severe mental disorder affecting about one percent of the population. It is characterized by paranoia, hallucinations, disjointed behavior, and social aversion (Xu et al 2010). Onset is typically during adolescence and early adulthood, and the illness is diagnosed using criteria from the DSM-

IV manual. A host of genetic, epigenetic, and environmental factors have been identified in its pathogenesis. Because of this heterogeneity and the influence of epigenetic and environmental factors, the identification of susceptibility genes has been very difficult. However, dozens of candidate genes and chromosomal loci

have been implicated using modern genetic tools. One such candidate gene is *DISC1*.

DISC1 was one of the first genes associated with schizophrenia. It is expressed in the brain, predominately in the hippocampus (James et al. 2004). It was first identified

Possible involvement of SMARCA2 (cont.)

in a large Scottish family in which affected members had a translocation involving chromosomes 1 and 11 that disrupts the *DISC1* gene.

DISC1 encodes a large protein with little sequence similarities to other proteins. However, it interacts with a number of other proteins that influence neuronal function at many levels including synaptogenesis, axonal transport, dendritic arborization, and synaptic activity (Millar et al. 2000). Although the *DISC1* translocation in this family is unique, genetic studies show that more subtle variants in *DISC1* are involved in schizophrenia in other families (Saetre et al. 2008).

Another risk factor associated with the development of schizophrenia is a microdeletion at the 22q11.2 locus. (Stark et al. 2008). This deletion is the highest known genetic risk factor, other than having an identical twin with the condition. It accounts for ~1-2% of schizophrenia cases. The region contains *DGCR8*, a gene which is involved in microRNA (miRNA) processing (Lee et al. 2010). Based on mouse knockout studies, *DGCR8* is viewed as a credible candidate gene for 22q11.2 associated schizophrenia (Stark et al. 2008). A significant portion of miRNAs are exclusively expressed in neurons. These observations suggest that miRNAs play a significant role in neural development and may be involved in the development of psychiatric disorders such as schizophre-

nia.

Unlike transcription factors, miRNAs function regardless of location in the cell. miRNAs bind with RNA-induced silencing complex (RISC) and either degrade or prevent the translation of target mRNAs post-transcriptionally (Lee et al. 2010). A reduction in *DGCR8* copy number results in downregulation of specific miRNAs (Stark et al. 2008).

An additional candidate gene for schizophrenia is ZNF804A, which codes for a transcription factor expressed in the brain. In addition to its involvement in schizophrenia susceptibility, ZNF804A is also associated with an increase in brain volume in patients (Donohoe et al. 2011). The ZNF804A risk allele (the minor allele in the single nucleotide polymorphism rs1344706) increases connectivity between the dorsolateral prefrontal cortex and the hippocampus (Donohoe et al. 2011).

Further complicating the inheritance patterns of schizophrenia are various environmental and epigenetic factors. Epigenetic is not synonymous with environmental; it merely denotes the covalent modification of DNA and chromatin by external factors, which may or may not be under the influence of environmental factors. Learning, memory, and the development of multiple neuropsychiatric disorders have been attributed to epigenetic modifications in neurons

(Hsieh and Eisch 2010). Epigenetic factors, in fact, play a crucial role in neural differentiation. Such factors include DNA methylation, histone modification, transcription factor expression, and expression of regulatory noncoding RNAs (Hsieh and Eisch 2010). Moreover, recent studies indicate that chromatin remodeling complexes play a role in DNA modification and neural differentiation.

SMARCA2 has been implicated to serve as a post-translational chromatin modifier. It encodes BRM, a component of a SWI/SNF-like chromatin remodeling complex in humans (Koga et al. 2009). The SWI/SNF complex was originally found in the yeast *Saccharomyces cerevisiae* (Koga et al. 2009). Multiple closely related complexes were later found in mammals. These multiple variants indicate that each varying complex may serve a slightly different role in the individual nuclear metabolisms of each cell. The SWI/SNF complex weakens DNA-histone interactions in an ATP-dependent reaction (Pazin and Kadonaga 1997).

One epigenetic factor implicated in schizophrenia is SMARCA2, which encodes BRM, a component of a SWI/SNF-like chromatin remodeling complex in humans (Koga et al. 2009). Originally, the SWI/SNF chromatin remodeling complex was found in *Saccharomyces cerevisiae*, a yeast (Koga et al. 2009). A



Junior Projects

Possible involvement of SMARCA2 (cont.)

closely related complex was later found in mammals. However, mammals have multiple variants, indicating that each variant may serve a slightly different role in nuclear function. In an ATP-dependent reaction, the SWI/SNF complex weakens DNA-histone interactions (Pazin and Kadonaga 1997). The complex's ATPase domain is BRM (Fry and Peterson 2001). *SMARCA2* is expressed in differentiating neurons and abnormal expression has been implicated in schizophrenia (Koga et al. 2009).

The effect of these various candidate genes on neural function can be studied in cell lines and in mouse models. However, it would extremely valuable to analyze expression and function in human neurons, in particular, neurons derived from patients with schizophrenia and other neuropsychiatric disorders. This has recently become possible with the discovery, in 2006, of induced pluripotent stem cells (iPSCs). These are derived from terminally differentiated somatic cells, such as skin fibroblasts, that have been are reverted back to a pluripotent state using when transformed with viruses and plasmids containing the transcription factors Oct4, Sox2, Klf4 and c-Myc (Takahashi and Yamanaka 2006). Although the main reason for developing these cells was to bypass the controversial use of embryonic stem cells for regenerative medicine, they are fast becoming the tissue of

choice for studying neuropsychiatric disorders since iPSCs derived from patients with schizophrenia, autism and other conditions, can be induced to differentiate into patient-specific neurons. Using iPSCs it is now possible to track epigenetic changes occurring during neural differentiation *in vitro*. The Lachman lab has been developing iPSC lines using skin fibroblasts from patients with schizophrenia and controls, and using this system we will identify genes that are regulated by the schizophrenia candidate gene, *SMARCA2*. Our goal is to identify gene networks that are disrupted in the neurons of patients with schizophrenia.

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Possible involvement of SMARCA2 (cont.)

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Calprotectin as a Predictor of Treatment Failure During IBD Steroid Taper, Ben Toll

Inflammatory bowel disease (IBD), which includes Crohn's Disease and ulcerative colitis, is an idiopathic and incurable condition often characterized by severe diarrhea, abdominal pain, and a relapsing-remitting cycle of disease activity. Although there are a number of ways to measure a patient's treatment response, none are at once convenient, inexpensive, and objective.

Fecal calprotectin is a 36kDa binding protein that makes up 60% of the protein in the cytosol of neutrophils, can last up to seven days before processing, and is easy and inexpensive to measure (4). Data supports the hypothesis that when found in stool, calprotectin suggests an influx of neutrophils in the bowel lumen and thus, functions as a specific marker for

intestinal inflammation (1-3).

Independent studies by Costa et al. and Tibble et al. have shown fecal calprotectin to be **predictive of disease relapse**. In 2003, Costa et al. used an ELISA test to measure calprotectin in stool samples of 131 IBD patients, 26 patients with intestinal neoplasms, 48 patients with Irritable Bowel Syndrome, and 34 healthy patients. With a 95% Confidence Interval, they found that median fecal calprotectin levels were significantly increased in subjects with Crohn's (231 ug/g), ulcerative colitis (167 ug/g), and neoplasms (105 ug/g), but not in the other two categories (22 ug/g for subjects with IBS and 11 ug/g for healthy subjects). Costa et al. also found that a fecal calprotectin level >150 ug/g was a strong predictor of disease relapse, es-

pecially in patients with UC (1).

In 2002, Tibble et al. measured calprotectin in stool samples from 43 CD patients in remission and 37 UC patients in remission, and found that median calprotectin levels in the relapse groups (122 mg/L for CD, 123 mg/L for UC; normal <10 mg/L) differed significantly ($P < 0.0001$) from those of the non-relapse groups (41.5 mg/L for CD, 29.0 mg/L for UC). In addition, their study showed that fecal calprotectin >50mg/L was 90% sensitive and 83% specific for determining disease relapse in UC and CD (3).

A 2006 study by Kolho et al. indicates that fecal calprotectin levels can also reflect a child's **response to steroid treatment**. Researchers measured calprotectin in 57 chil-



Ben Toll presents his project at the Science Research Symposium.

Junior Projects

Calprotectin as a Predictor of Treatment Failure (cont.)

Mentor:
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dren who underwent colonoscopies and followed-up in 15 children who were given steroids to manage their IBD. Fecal calprotectin was less than 100 ug/g in 70% of the children with normal findings on colonoscopy or a non-IBD disease, while fecal calprotectin was greater than 100 ug/g in all but one child with active IBD and in 13/15 of those children who were introduced to glucocorticoids by clinicians. For children with active IBD, calprotectin values declined as symptoms improved, but seldom fell into the normal range (2).

We will be testing whether fecal calprotectin can be used to predict steroid taper failure. Although steroids are commonly known to quickly and effectively reduce inflammation, the length of the steroid course must be optimized to be effective. Insufficient exposure may lead to a resurgence in IBD related symptoms, while prolonged exposure may lead to reduced bone density, muscle breakdown, and weight gain as well as growth impairment and pubertal delay in children. Thus, doctors must remain cognizant of the length of their patient's steroid course.

But even when a patient is ready to come off of steroids, one cannot simply terminate treatment. Our adrenal glands naturally produce a low level of steroids (aka the hormone cortisol) to increase blood sugar levels, suppress the immune system, and aid in fat, protein, and carbohydrate metabolism. Because steroids flood the body with excess cortisol, the adrenal

glands stop producing their own. Abrupt termination of steroid treatment will not give the body enough time start producing cortisol again, and acute adrenal crisis -- a life threatening condition - may result. So doctors must balance the risks of IBD, glucocorticoids, and acute adrenal crisis, when tapering their patients. The problem, however, is that they must to rely on the patient's reporting, their own intuition, and the occasional but expensive colonoscopy to do so.

Some studies, like Kolho et al., have looked at both steroids and fecal calprotectin; none, however, have used calprotectin as the tool to plot the course of the taper. This will be the main goal our study. Employing a newly validated Point of care (POC) device, Dr. Higgins' lab will obtain fecal calprotectin measurements from patients and then **assess the value of fecal calprotectin as a disease activity marker and a predictor of future relapse**. Calprotectin will hopefully prove effective in assessing patient status and setting optimal tapers at which both steroid and IBD relapse risks are minimized.

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The Effect of Estrogen on the Perceived Sweetness of Miraculin , Shivane Shah

Imagine being able to drink Tabasco Sauce straight out of the bottle and perceive it as a glazed donut (Farrell & Bracken, 2008). This is possible with miracle fruit. Miracle fruit is a tiny red berry with a large seed covered by a thin layer of pulp that contains Miraculin (Bartoshuk et al., 1969). Miraculin is a taste modifying protein. Miraculin is the cause for the suppression of the sour taste and making it seem sweet. To activate the effect of miracle fruit, one must hold the pulp of the berry in their mouth for a few minutes. After swallowing the pulp, the Miraculin will continue to alter the taste for a half an hour to an hour (Bartoshuk et al., 1974). The berry itself has no taste (Kurihara and Beidler 1969). For example, if one consumes lemons with miracle fruit, they may seem sweet but the acids continue to work as acids and can be harmful if consumed in large quantities.

This plant is native to West Africa and for hundreds of years miracle fruit was used by native Africans to suppress the bitterness and sourness of palm wine and make maize dishes palatable (Daniell et al. 1952). Miracle fruit is difficult to cultivate outside of its natural environment, because it needs to be in a tropical environment with no frost and needs a certain pH level to grow successfully. But, it has been successfully grown in Florida (Sun et al., 2006). Also, Miraculin has been suc-

cessfully transferred into genetically modified lettuce, tomatoes, and strawberries (Sun et al. 2006, Sun et al. 2007, Sugaya et al. 2008). The taste alteration made by Miraculin is much sweeter compared to the same amount of sucrose; 0.4 μM of Miraculin is three thousand times sweeter than the same amount of sugar (Kurihara and Beidler 1969). The concentration of Miraculin can reach up to 10% of the total soluble protein in miracle fruit (Sun et al., 2006). It is unknown how the protein specifically works with the taste buds, but it is known that the protein does not block the sour taste receptors (Bartoshuk et al., 1974).

The taster status of each individual is different, it is important to see if the status affects Miraculin in a significant manner. Oral sensation differs genetically. Some common genetic differences are in the ability to taste 6-n-propylthiouracil (PROP) and phenylthiocarbamide (PTC) and in the density of fungiform papillae. PROP is used by many scientists in taste research and is known to be safe and have no adverse effects. Fungiform papillae are located on the tongue and they hold the taste buds. PROP is a tasteless substance to some, while it tastes extremely bitter to others. The ability to taste PTC and PROP results from a dominant allele. Those who cannot taste it must have two recessive alleles. An increased

number of fungiform papillae and being able to taste PROP and PTC makes a person a supertaster. A supertaster experiences all tastes at an intensified level. Many times particular substances taste overly bitter, such as Brussels sprouts and asparagus (Duffy and Bartoshuk 2000). Understanding how Miraculin affects the various types of tasters is important because it may help better comprehend how the protein functions, as well as how taste sensations are encoded.

With hormone fluctuations, come variation in the sweet taste, with this knowledge, it is important to understand if Miraculin is affected as well. The hormone levels for women change from childhood, to puberty, menstruation, pregnancy, and menopause. Fluctuations in reproductive hormones have been shown to influence sensory functions, including visual, auditory, and olfactory thresholds for women (Doty et al. 1981, Friedman et al. 1978, Parlee et al 1983, Swanson et al. 1988). Sex differences in taste responses have been reported in numerous species, including rats and humans. The effect depends on factors including the tastant, concentration, and species. However, in humans the sweetness threshold is highest during preovulation, when estrogen levels are increasing (Than et al. 1994).

The goal is to understand how



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Junior Projects



*Shivane Shah
Presents her project
at the White Plain
Invitational for
Sophomores
in 2010*

estrogen impacts the sweetness induced by Miraculin. We hypothesize that effects induced by Miraculin will be similar to estrogen by having the highest threshold during high levels of estrogen.

With its effect to suppress sour taste and make it seem sweet, Miraculin could be very useful in everyday life. Patients undergoing chemotherapy often complain that food is unpalatable because of a metallic taste lingering in their mouth. With the addition of Miraculin, one could taste food without the pungent taste. It could be beneficial for the nausea caused from bitterness commonly experienced by pregnant women because Miraculin could prevent the bitterness. Diabetic patients can eat apparently sweet tasting foods without worrying about their blood sugar levels. And for people wanting to reduce their weight, the addition of Miraculin to their diet can reduce the usage of sugar and artificial sweeteners. In addition to pregnancy, these conditions are likely to be experienced by women, as rates of breast cancer are increasing, and women are more likely to be obese and diabetic. Thus, testing to see if estrogen affects Miraculin may lead to useful advances for women's health issues.

Specific Aims:

Sweetness from sucrose has been shown to vary across the menstrual cycle. When estrogen levels are high, the threshold for sucrose is the lower compared to when estrogen levels are low. (Than et al. 1994). The

purpose of this study to see how variations in estrogen level affect the sweetness induced by Miraculin. To accomplish this, the following aims will be tested:

Female subjects, between the ages of 14-18, will be tested to compare estrogen levels and the taster status determined by their PROP rating. This would show whether taster status is affected by estrogen.

Another comparison would be between the level of estrogen and the perceived sourness from citric acid. This would show if the perceived taste of sour is affected by estrogen.

And thirdly, a comparison between estrogen levels and the perceived sweetness of citric acid with the addition of Miraculin would be done. From this comparison, one could see if the sweetness caused from the Miraculin is affected by variation in estrogen level.

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A Study of the Preferred Habitat of Tropical Fishes Displaced to Long Island by the Gulf Stream, by Alex Alves.

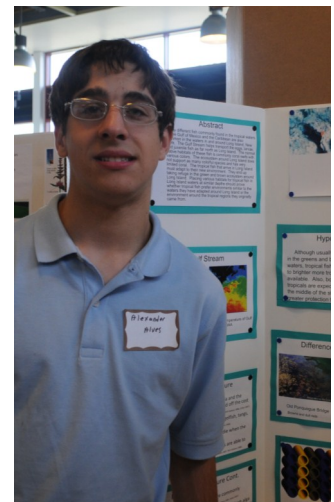
The waters off long island are host to many tropical fish (Paparo 2007, Rich Galiano 1996, Cohen 2007). Although most people believe that the tropical fish can only survive around Florida, this is far from the case. The gulfstream helps transport these fish to Long Island. Once there, the shallow bays provide a location for the fish to survive into the latter months of summer and fall until the water becomes too cold (Paparo 2007, Rich Galiano 1996).

The gulfstream itself is sole responsible for transporting these juvenile fish. The gulfstream is warm water current which transports the water north (Paparo 2007, Rich Galiano 1996). The lifecycle of these fish follows. The adult species reproduce in the waters in the Gulf of Mexico. The microscopic eggs and

larvae are then sucked into the Gulf Stream. The larvae fish are too small to fight the current and thus are carried north along with it. As they travel north, the larvae fish grow and become juveniles. However they are still forced to stay in the Gulf Stream as the pelagic water surrounding the current is far too cold. As the summers continues, the Gulf Stream moves closer to Long Island, being around 200 miles off shore. With the help of even a small storm, pockets of water can be pushed closer to Long Island. Once at the shores off long island the fish seek out the warm shallow waters of the bays. The shallow bays are able to be heated by the sun to the point where the water is warm enough. Unfortunately for the majority of the species their time is limited, as the winter months will bring colder water, and

they still will not be old enough to swim south (Paparo 2007, Rich Galiano 1996).

Although the water temperature may seem to the fish as in the normal range, there can be many differences between their normal tropical environment and the environment of Long Island (Paparo 2007, Rich Galiano 1996). The largest difference is in visibility (Rich Galiano 1996, Cohen 2007). The waters off Long Island are fairly cold and thus allow many different species of algae to develop (Paparo 2007, Rich Galiano 1996). These species are able to survive in the warmer waters. The extremely high algae count is a stark opposite to the low algae count in places such as Florida (Paparo 2007, Rich Galiano 1996). From personal experi-



Alex Alves present his project at the White Plains Invitational for Sophomores in 2010

Junior Projects

A Study of the Preferred Habitat of Tropical Fishes (Cont.)



ence I can say that the waters in Long Island can sometimes be filled with so much algae that you can not see your hand in front of you. The increase in algae also has many effects on the ecosystem. The first simple one being that the algae decreases the visibility in water. This means that in green to brown tinted water the neon colored tropical fish will stand out. Another effect of the algae is that it changes the amount and type of dissolved minerals in the water. Another big difference between their normal range and Long Island is that the temperature in Long Island fluctuates much more. The bays are warm enough to allow the tropical fish to survive, because they are shallow and the sun heats them up. However due to the natural tide cycle, in an incoming tide cold water from the deeper ocean comes into the bay, decreasing the temperature. Fluctuations such as this are not as large in the native range of these fish. I predict that despite all these differences that the fish will instinctively tend to favor habitats that are similar to these which they favor in their normal range (Wilson 2010).

Methods

For this project, I introduced artificial habitats to control variability in habitat construction and location. In total, I built three separate habitats. The basic structure for each of the habitats is a honeycomb design of 6 PVC pipes. The lengths of the pipes varied in length and two sizes of diame-

ter were picked. Each habitat had two of these PVC honeycombed on them, one mounted vertically and one mounted horizontally. Varying the length and orientation of the PVC pipes help simulate many different habitats. The vertical tubes act as sponges when the horizontal act more like stepped coral. The base of each of the habitats was constructed using a cement block. The weight of the cement block would anchor the habitat securely to the bottom during rip tide. This was necessary as the location is known for having a strong current. The other advantage of the weight of the cement block is that it would deter anyone from taking the project or using it as a location to collect tropical fish. The final advantage of the cement block is that in itself it gave another hiding habitat inside the block itself.

The total of three habitats where placed in water between 1 and 2 meters deep. The distance between the habitats was approximately 2 meters, this made them far enough from one another that they were not visible, but close enough so that fish have a high percentage of seeing the habitat in the low visibility water. In addition the habitats were connected via a length of bright yellow polypropylene rope. This would also help attract any fish swimming between the structures. Finally a float was added to the habitat closest to the inlet to attract any floating fish.

A total of three locations were chosen. The primary concern when choosing a location was the distance from the inlet. The inlet allows all the water into the bay, thus the fish. A fish is more likely to be found around the mouth of the inlet compared to the other side of the bay. Another factor for choosing the locations was the human usage of the area. An area that is common for beach goers can suffer from unintentional disturbances. Even worse is the chance of tropical fish collectors who would intentionally take fish from the habitat. This forced me to reject the number one spot for tropical fish in Long Island as the location is frequently picked trough by tropical fish collectors. The final thing to consider when picking location is the number of alternate habitats in the immediate area. By choosing a location with few other options in terms of shelter, any fish that do pass the shelters will be forced to take refuge in them. In the end, I picked three locations, two directly across the bay from the inlet, and another adjacent to it.

Results

The first location did not reveal any results. I believed that this was due to the location of the project and moved it to the second location. In the second location, a single snowy grouper was found in one of the vertical tubes. The move to the third location was done completely underwater and it was not necessary to remove the fish from the habi-

A Study of the Preferred Habitat of Tropical Fishes (Cont.)

tat. The snowy grouper remained in the structure as it was moved to the shallower, third location. At the third location the snowy grouper remained, but in addition a northern kingfish was also spotted around the cinderblock base. The single snowy grouper did show a strong preference to the vertical tubes as it would appear in different vertical tubes, but was not found once in the horizontal tubes.

Conclusion

The results of the experiment are not enough to prove or disprove the hypothesis. The sample size was far too small to decide anything definitively. This can be the result of many different factors, but does not indicate a failure in the project itself. I believe that the main reason for the small sample size is the year itself. In Long Island the number of tropical fish vary considerably every year. Some years there will be thousands and other practically none. The fact that Atlantis Marine World also had little successes in tropical fish collection this year indicates that it was an overall bad year for tropical fish in Long Island. When patterns variations in the Gulf Stream can alone be responsible for the lack of tropical fish, this year there could be another factor. The BP oil spill in the Gulf of Mexico has had some devastating effects on the environment there, many of which are still unknown. It is plausible that the oil affected the spawning of the fish in the

Gulf of Mexico and in the south Atlantic. If this was the case, the number of Larva in the gulf stream would decrease substantially (NAS 1975).

The reasons stated above are based off the lack of tropical fish as a whole. However in addition there are other things that could have added to the lack of a sample size. Although the locations were picked carefully, it is still possible for the locations themselves to be an issue. Factors such as the flow of water in the bay, the distance to docks and others can have an effect. I believe that the reason the first location failed to give any results could be because of a sandbar redirecting the water from inlet around the location. The second and third locations are close to a large dock, it is possible that the tropical fish took refuge in the dock before they had an opportunity to go to my project. Another possible downfall of the second and third locations could be the current. At certain times of day the current in the location moves extremely fast. Although this would make the need for a shelter increase, it would also make it more difficult for certain fish to get to the shelter once spotted. One thing that could have affected both locations would be if a large predatory fish such as a striped bass, bluefish, or large spotted grouper knew the location of the shelter. If one of these predators knew the location of the shelter, they would use the shelters as a means to lure fish into a location and then be

able to eat the fish there. If this was the case only the smallest fish would be able to hide in the large vertical tubes such as the snowy grouper did. Although any of these factors above can be responsible for the lack of data, I believe that the combination of all of these explain the lack of data. Further experiments will be conducted in more diverse locations next year.

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Sophomore Project

Potential replacements for platinum catalyst in PEM fuel cells, Alexis Mangual

Polymer Electrolyte Membranes or PEM fuel cells are fuel cells that operate by splitting hydrogen into protons and electrons at the anode side of the electrolyte. The electrons are transported into a separate load in which they are used to generate a current while the hydrogen ions travel across an electrolyte layer. Once the ions have reached the cathode side, the hydrogen ions recombine with the electrons and oxygen to form water. PEM fuel cells are efficient at converting energy stored in hydrogen into electrical energy having only water as a byproduct making this a strong candidate for replacing gasoline (Wang et al). However, on the anode and cathode layer, there is a catalyst coating which presents a major problem for this technology. The catalyst is a major part of the fuel cell as it facilitates the reactions that take place and it strongly influences the current density and overall efficiency of the system (Yan and Wu, 2007). This catalyst is often platinum as platinum is the only commercially available material capable of performing efficiently in a fuel cell while withstanding the high acidity levels. Platinum presents two major problems for being used in a fuel cell. First of all, platinum is what causes the major difference in overall initial cost of fuel cells as compared to standard gasoline engines (Sun, Ogden, and Delucchi, 2010). Although the initial cost is high, the overall lifetime cost of a fuel cell vehi-

cle is relatively similar to that of a standard internal combustion engine (Sun, Ogden, and Delucchi, 2010). Second, platinum is subject to thermal as well as carbon monoxide poisoning in the catalyst layer which can lead to an overall decrease in surface area and therefore an overall decrease in efficiency (Aindow, Haug, and Jayne, 2011). The apparent problems with using platinum as the catalyst in PEM fuel cells has lead to major research in a replacement catalyst that can be as efficient, more cost effective, and be able to withstand the same conditions as platinum.

Many new catalysts have been considered for replacing platinum in fuel cells. Some are platinum based alloys which incorporate the positive properties of platinum with other less expensive materials that are also less efficient to create a balance between cost and effectiveness. However, these Platinum based alloy catalysts share very similar characteristics to Platinum in the speed at which they lose surface area in the cathode side therefore gaining not only the advantages of Platinum but also one of the main disadvantages (Mercado and Popov, 2005). On the other hand, there are non-platinum catalysts that have the advantage of being far less expensive but exhibit substantially lower current densities to those generated by a platinum or platinum based cata-

lyst (Olson, Chapman, and Atanassov, 2008).

One such catalyst considered to replace Pt was PtNiZr which was made adding Zr to PtNi. The alloy was created as a viable alternative to Platinum in PEM fuel cells while also having increased resistance to corrosion as compared to Platinum (Whitacre, Valdez, and Narayanan, 2007). Increasing the overall amount Zr in the alloy over 5% found a decrease in overall power density possibly due to the occupation of potential Pt surface area sites by Zr. However in the configuration of Pt59Ni39Zr2, the alloy provided a 300% increase in current density when compared to pure Pt meaning much higher energy output however did not provide the durability that was originally sought after (Whitacre, Valdez, and Narayanan, 2007). Another such alloy was the Pt_xNi/C configuration where x could be anywhere from 1 to 3 (Wu, Wexler, and Wang, 2009). The objective of this catalyst was to reduce Pt loading while maintaining or even increasing the overall catalytic activity in the ORR (oxygen reduction reaction). Through multiple test, they found that the overall catalytic reactivity of the Pt alloy was on par or even greater than that of pure Platinum by partially replacing the Platinum with Nickel (Wu, Wexler, and Wang, 2009). The configuration of Pt3Ni1/

Potential replacements for platinum catalysts (cont.)

C which was shown to be highly efficient was studied for its overall durability. The results found that the configuration also showed high resistance to sintering increasing its overall durability (Mercado, Kim, and Popov, 2004). This catalyst not only exhibited an exceptionally high power output as shown by Wu, Wexler, and Wang but also was durable and more cost effective than pure platinum. This catalyst showed clear signs of being a viable option as a Platinum based alloy catalyst for future PEM fuel cells.

Another recently discovered catalyst also based on the PtNi/C configuration was put to the test for performance and durability. The study conducted looked at Pt1Ni1/C as a potential configuration when compared to regular Platinum. In this PtNi/C configuration, they found a decrease in overall power output due to the decreased ORR caused by the corrosion of the Ni (Cho et al). Although the PtNi/C configuration shows a lot of promise, in the Pt1Ni1/C configuration, the lower ratio of platinum to nickel causes a decrease in durability and overall performance (Cho et al).

There is still another potential configuration to replace Platinum in fuel cells being the PtPd/NMCC and even the Pt/NMCC (Nitrogen Modified Carbon Composite). The results showed that when Pt3Pd and even pure Platinum are supported by NMCC, they possess a much higher stability

than regular carbon supported Platinum and also have an increase in power due to the increase in the surface area of the catalytic areas (Li, Park, and Popov, 2009). This Pt3Pd/NMCC provides a substantial power output with an increased stability from that of Pt/C as well as being less expensive as Pt/C due to less space for Pt where Pd is located.

On the other hand, there are the non-platinum catalyst which have their own advantages but also provide their own disadvantages. One such catalyst was Tantalum Oxide (Ta₂O₅) which was carbon supported by a thin carbon paper (Kim et al, 2010). The Tantalum Oxide was found to be chemically stable under the pH conditions inside the ORR on the cathode side however it did not exhibit the power output that Platinum or Platinum based alloys could produce (Kim et al, 2010). The problem with Tantalum Oxide is that it tends to have poor electrochemical performance due to its poor conductivity. The Tantalum Oxide was found to have a 9% current density to that of Platinum at best providing a 1/3 the power output when carbon supported (Kim et al, 2010). The fact was that although the Tantalum Oxide is a solid competitor to Platinum as the catalyst for fuel cells, its catalytic reactivity had to be drastically improved before it could even be considered as a replacement for Platinum or Platinum based alloys (Kim et al, 2010).

Overall, the non-platinum catalyst are less commonly studied because they lack the power output for which Platinum is used in the first place. In a real fuel cell vehicle the power generated by a catalyst like carbon supported Tantalum Oxide would not provide enough power to push forward a car at the capacity at which a standard internal combustion engine could.

Non-platinum based catalyst present disadvantages that are at the moment far too great for them to be a viable replacement to Platinum. The main problem is the lack of power which could be improved in future studies but currently makes this class of catalyst unfeasible. At this point the only viable catalyst to replace Platinum are Platinum based alloys that are effective but still somewhat expensive. Overall, non platinum catalyst such as Tantalum Oxide exhibit the most promise in the future if we find a way to increase the overall power output. Until the technology to create efficient non platinum catalyst for PEM fuel cells is available, platinum based alloys are a viable option that can serve as an important bridge between platinum and no platinum.

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Sophomore Project

Potential replacements for platinum catalysts (cont.)

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Notes