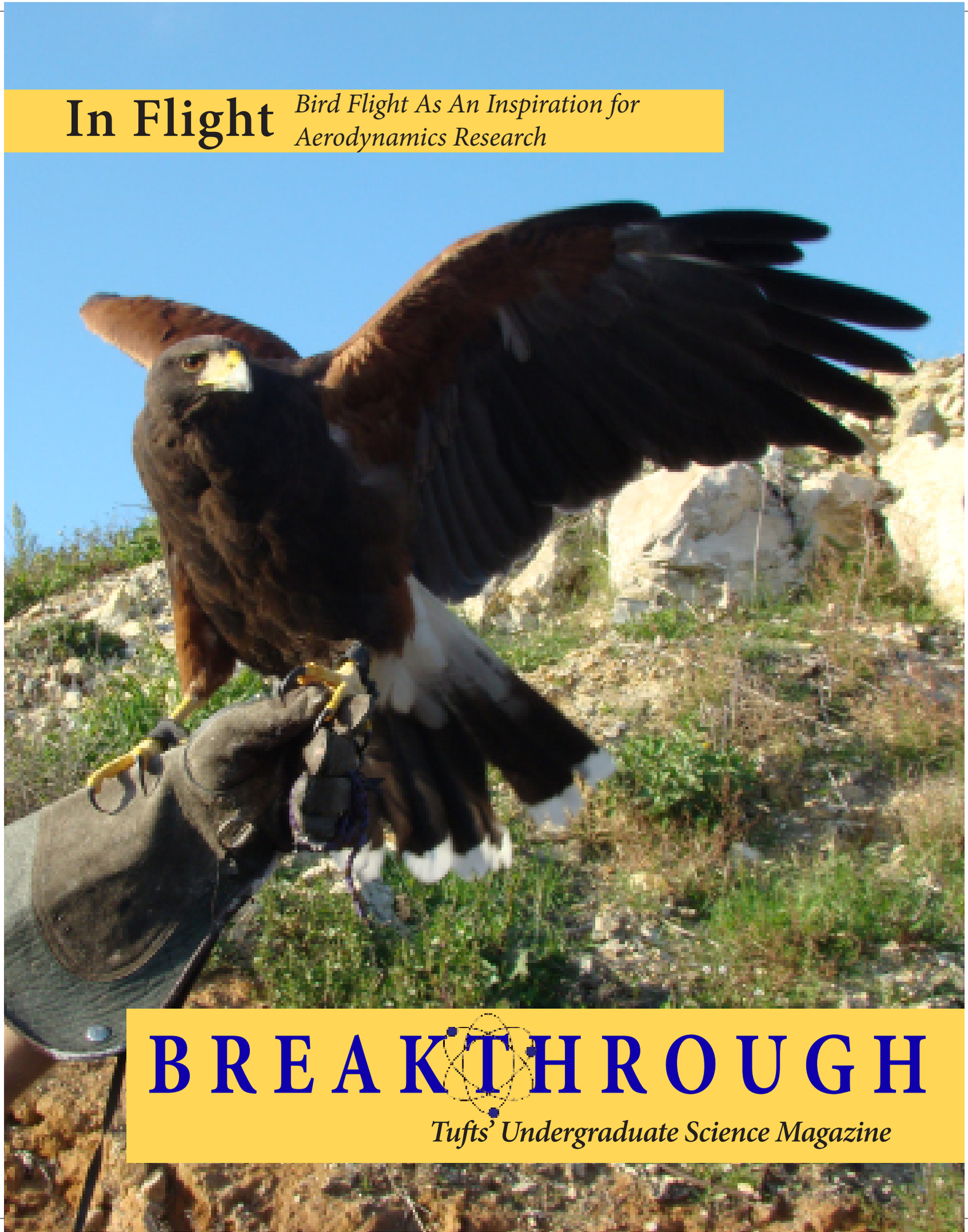
In Flight

Bird Flight As An Inspiration for Aerodynamics Research



BREAKTHROUGH

Tufts' Undergraduate Science Magazine

FROM THE EDITORS

Dear Readers,

This issue, we're continuing our transformation into a more accessible and easy-to-read science and technology magazine. You'll notice some key differences in this semester's issue: our layout is more dynamic and engaging and our articles are arranged to allow you to glean key pieces of information at a moment's glance. We've made these changes for a reason. We believe that an understanding of current trends in science and technology are critical to the success of today's students and recent graduates. Yet, science is only as good as its level of accessibility. We're here
to continue to report on the most exciting topics in an easy-to-understand way so, regardless of your background, you can stay up to speed on the most important scientific breakthroughs.

In this issue, we cover a variety of exciting topics. You can find out about anything from defense mechanisms in plants, to obstacle avoidance in airplane autopilot systems, from why women still struggle to make inroads in science to the burgeoning field of optogenetics—the use of light to activate genes. We profile the Geology Department and offer a glimpse into undergraduate research. We even have a fun science experiment that you can use in the confines of your dorm to impress your friends during late-night shenanigans.

We know, it's really exciting. So quit reading this boring letter from us and flip on through to the fun and informative articles that follow! As always, thanks for reading!

Warmest Regards,

Dan Slate and Lauren Wielgus
Co-Editors-in-Chief

Cover image courtesy of Lucia Smith.

OUR STAFF

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Join Us!

Want to submit an article or join our staff? Come to one of our meetings (Wednesday nights, 9 p.m., Campus Center Large Conference Room) or e-mail us at tuftsresearch@gmail.com.

Inside the Mind

Optogenetics: "Lighting Up" a New Path in Medicine

Have you ever wanted the ability of mind-control? Radical ideas of the sort commonly displayed in sci-fi movies may not be so unrealistic after all. With the recent developments in the field of optogenetics, the realm of the human brain may at last be fully navigated—and eventually controlled. A truly pioneering science, optogenetics has become the forefront in the study of neurological processes and will eventually enable scientists to manipulate these processes.

Optogenetics is a science that combines the use of genetics and light optics to control how cells work. In a way, this is "mind-controlling" certain cells to perform specific processes. This is made possible by using promoter genes in cells, a type of "on-and-off" switch that controls the activation of certain cell processes. This is done by finding cells that respond to light, then shining a light only on these cells to activate their processes. Neurons send electrical pulses across membranes when ions are charged and excited. Light can be used to create an electric potential identical to the one needed for the neurons to become active, with the help of light-sensitive proteins found in cells. This procedure is highly precise and selective, since the light must target only certain cells. Precision is especially crucial in not disturbing other cell processes, which could lead to undesirable or nonexistent results [1].

Optogeneticists have summarized the procedure of conducting optogenetic research in six fundamental steps. First, a promoter is created to carry out gene expression, particularly one for encoding opsin, which is a certain protein needed for light reception. Second, this promoter is placed in a virus, which is then injected into the brain. An optrode, a fiber-optic cable with an electrode, is then placed into the brain. The cable shines different wavelengths of light onto neurons to excite their ion channels, and finally electrophysical and behavioral results are recorded [2].

Scientists at Stanford University have come a long way in identifying certain opsins that control specific neural impulses. Experiments involving the use of channel rhodopsins have been largely successful. Channel rhodopsins are able to turn neurons on and off, especially in a safe manner in response to light. This is because there are large amounts of all-trans retinal in mammalian tissues, a chemical that is necessary to activate microbial opsins by photons. Such a large quantity of the chemicals allows for only one opsin gene to be added to neurons, which further facilitates the procedure.

Since 2006, more opsins have been discovered and applied with fiber-optics that are more precise and efficient, and can be applied to a wider scope of the brain. Now, scientists can dispense light to any part of the brain and can observe the electrical potential in neurons that direct motor control while simultaneously controlling these circuits with opsins [1].

Optogenetics has also proved to be promising for future medical applications. The discovery of new proteins sensitive to optics can allow scientists to investigate how certain brain circuits cause behavior, which could lead to eventual breakthroughs in better understanding psychiatric diseases and treatment. For example, the company Eos strives to treat blindness using optogenetics.

Optogenetics has also been used to further develop medical imaging technologies such as fMRIs (function Magnetic Resonance Imaging), which are used to scan the brain. Other applications include treatments for spinal cord injuries, Parkinson's disease, and depression [3]. Professor Fiorenzo Omenetto, a professor of biomedical engineering at Tufts and recently a featured speaker at the lauded TED Talks, has done extensive work on optics and expresses much hope for the future of optogenetics. His work on developing sustainable biomaterial made from silk has a great outlook for a future of advanced and environmentally friendly medical technology. According to Professor Omenetto, developments in this science can advance "seizure control, reverse depression, and access and retrieve memories," making the analogy of the brain to a computer seem more realistic. However, in regards to the accessibility of these technological applications to the general public, Professor Omenetto shares his concerns. Since optogenetics is still a relatively new concept, Omenetto says "[it] needs a lot more validation and regulatory approval, so it will be at least a decade away before [it] can be of real use to the general population."

Whatever limitations and unknowns this science may have, its prospects still seem encouraging. With the combination of genetics and target-medicine treatment, it is impossible to ignore the potential for more accurate, efficient, and effective treatment in the future of medicine.

Story by Ming Lin, a freshman majoring in anthropology.

"Cell" Phone

A Collection of Studies on How a Common Technology, the Cell Phone, Affects Our Health

Photo Courtesy of Getty Images.

Cell phones are one of the most ubiquitous kinds of technology in the world; they travel with us virtually everywhere we go. It is nearly impossible to go an entire day without seeing a cell phone, let alone using one. With such a massive increase in cell phone usage, scientists around the world have investigated (and continue to investigate) the possible side effects to our health the technology carries. The most alarming consequence of prolonged cell phone use, suggested by several studies, is brain cancer [1]. Is this actually a scientific correlation, or just scare-mongering cynicism? And what, if any, other health effects exist from using cell phones?

Like most other electronic devices, cell phones emit an electromagnetic field [1,2]. The type of radiation that cell phones emit is non-ionizing, meaning it is not powerful enough to break down molecular bonds, such as those in DNA [1]. Located mostly in the antenna area of the cell phone, this radiation is weaker than radiation emitted by an airport security scanner, or the much more harmful ionizing radiation that can affect DNA, found in x-rays [2]. With no mutations in DNA, it would seem that there would be no basis to question the benign radiation of cell phones, but the effects of radiation could extend beyond DNA to proteins, especially those that are involved in tumor suppression, DNA repair, and cell division.

Studies on cell phone use and a possible relation to cancer have been continually met with harsh criticism and controversy from the scientific community. Experimental fallacies, false memories from interviewed individuals, and funding from cell phone companies and wireless trade groups often generate controversy and undermine the results of each study. Since studies are conducted over decades, it is also extremely difficult to label standards of "heavy" or "low" cell phone usage among their subjects while society simultaneously increases its daily use.

In an attempt to avoid these shortcomings, the research group "Interphone" (part of the World Health Organization and comprised of 13 different nations), conducted research for over a decade on cell phones and their effect on brain cancer [3]. The researchers studied a total of 10,751 people, with over half the subjects being sufferers of glioma or meningioma, the two most common types of brain cancer [4]. By comparing and grouping individuals based on how often and on what side the subjects talked into their cell phones, the research team was able to calculate the likelihood of developing "ipsilateral" tumors, or tumors that developed on the same side of the brain that the cell phone occupied the most. Although there was a high correlation of ipsilateral tumors at the highest exposure level to cell phone radiation, the team concluded that, overall, there was "no increase in risk of either glioma or meningioma" with higher use of cell phones [3,4]. The results concur with the majority of research on the topic, including a study conducted by the National Institutes of Cancer that found no correlation between cancer prevalence and rates of cell phone use from 1975 to 2005 [1,3].

Despite its broad study base and length of research, however, the Interphone study has been met with much of the same criticism as other studies with the same conclusion. The main criticisms cite its scope; many believe that the potential harmful risks of cell phones can't be measured just by one form cancer, and that possible effects on glial cells (brain tissues that support and protect neurons) and the immune system must also be considered [3]. Finding every possible factor within this capacity is challenging, but research is continually growing.

To see how metabolism of the brain cells is affected by cell phone radiation, a team of researchers at the National Institutes of Health found that cell phones significantly increased brain activity when exposed to the head for less than an hour. The experiment, conducted in 2009, used an apparatus that was placed on the heads of their 47 test subjects, with one phone on each side of the head. The researchers could then measure brain activity according to glucose metabolism, measured via positron emission tomography, or PET scans. In one scan, both phones were turned off, but in a second scan, the right-sided phone was turned on, while a 50-minute, muted message played. Comparing the PET scans, the researchers saw a 7% increase in glucose metabolism in an area of the brain near the "on" phone's antenna [2]. Importantly, the study was able to distinguish from the increased activity seen because of heat emitted from the phone and radiation, since the bulk of the phone did not directly touch the subjects' heads [2]. This means the raised level of activity was solely due to the cell phone's non-ionizing radiation. Is this increased activity necessarily a bad thing? The implications are unclear, according to the research team, but these findings open doors to studying new, possible mechanisms for cancer development caused by cell phones [2].

Aside from cancer, uncertainty also exists in regards to short-term health effects of cell phones. The Centre for Mobile Communications Research at Loughborough University found that test subjects exposed to extremely low frequencies (ELF) of cell phone radiation in a "talk mode" took significantly longer to fall asleep than those exposed to no cell phones or phones in a "standby" mode [5]. In contrast, some research has suggested that cell phones may actually improve our health. In an experiment by the University of South Florida, researchers found that exposure to the electromagnetic waves of cell phones destroyed the harmful brain protein beta-amyloid, which is thought to cause Alzheimer's disease [6]. This discovery could lead to potential therapies for the disease, and even for soldiers suffering from brain trauma due to blasts, where beta-amyloid buildup is common [6].

So should we continue using our cell phones, or are the risks too dangerous? Unfortunately, with conflicting and inconclusive findings on both sides of the debate, a definitive answer has yet to be found. Abolishing cell phone use completely for protecting our health appears radical and unnecessary, but small, precautionary steps, such as holding the phone away from your ear, or using a headset, can still be taken in case our fears are found to be true.

Story by Stephen Walsh, a freshman majoring in Biology.

Photo Courtesy of Getty Images.

In Defense Of Plants

Tufts Professor Colin Orians examines how plants respond to their (very) numerous antagonists.

Plants are virtually the only land-based organisms capable of capturing energy from the sun. As such, they have spent millennia under selective pressure from free-riders like us, and it's not surprising that the ones who made it through all that time are no longer helpless. Plants have a variety of tactics against herbivores, including spines (think roses), poisons (nicotine), and irritants (ever had poison ivy?) [1]. Some species even emit odors meant to attract predators of herbivores in an "enemy of my enemy is my friend" approach [2].

In a pair of recent papers, Tufts Professor of Biology Colin Orians (pronounced OR-ee-anz) elucidates yet another response to herbivory: changes in resource distribution. The work was done using tobacco and tomatoes, and Orians' collaborators were from the Brookhaven National Laboratory, the University of Rhode Island, and Johannes Gutenburg University in Mainz, Germany.

The advance that allowed Orians and colleagues to proceed with their studies is a new way of introducing a radioactive tracer. Radioactive or fluorescent tracers have been important in previous biological experimentation; in notable examples, they have revealed relationships between different compartments of complex cells and have helped explore the interplay between plants and root fungi [3]. The particular tracer used in this research was a radioactive isotope, ^{13}N (pronounced "nitrogen thirteen").

Plants have a variety of tactics against herbivores, including spines (think roses), poisons (nicotine), and irritants. (Ever had poison ivy?)

Nitrogen 13 is valuable because it decays quickly, with half of any given sample turning to carbon in just ten minutes. According to one of the papers, "One of the advantages of using short-lived radioisotopes is that they do not accumulate in the plant…retests can be performed over time and after treatment, allowing the same plant to be used as its own control,"[4].

Previously, researchers had only been able to introduce radioactive nitrogen as part of the nitrate ion (NO^{3-}), which is absorbed through the roots of the study organism. In this study, though, Orians and colleagues could add nitrogen straight into the leaves as gaseous ammonia: "Our focus is, how is the leaf changing?" Ammonia enters the leaves through stomata, pores that also regulate transit of CO_2 and water. In the leaf tissue, it dissolves easily, morphing into the ammonium ion (NH_4^+). Combined with the short half-life of the isotope, tests of how plants use nitrogen can now be performed with more temporal and anatomical precision than ever.

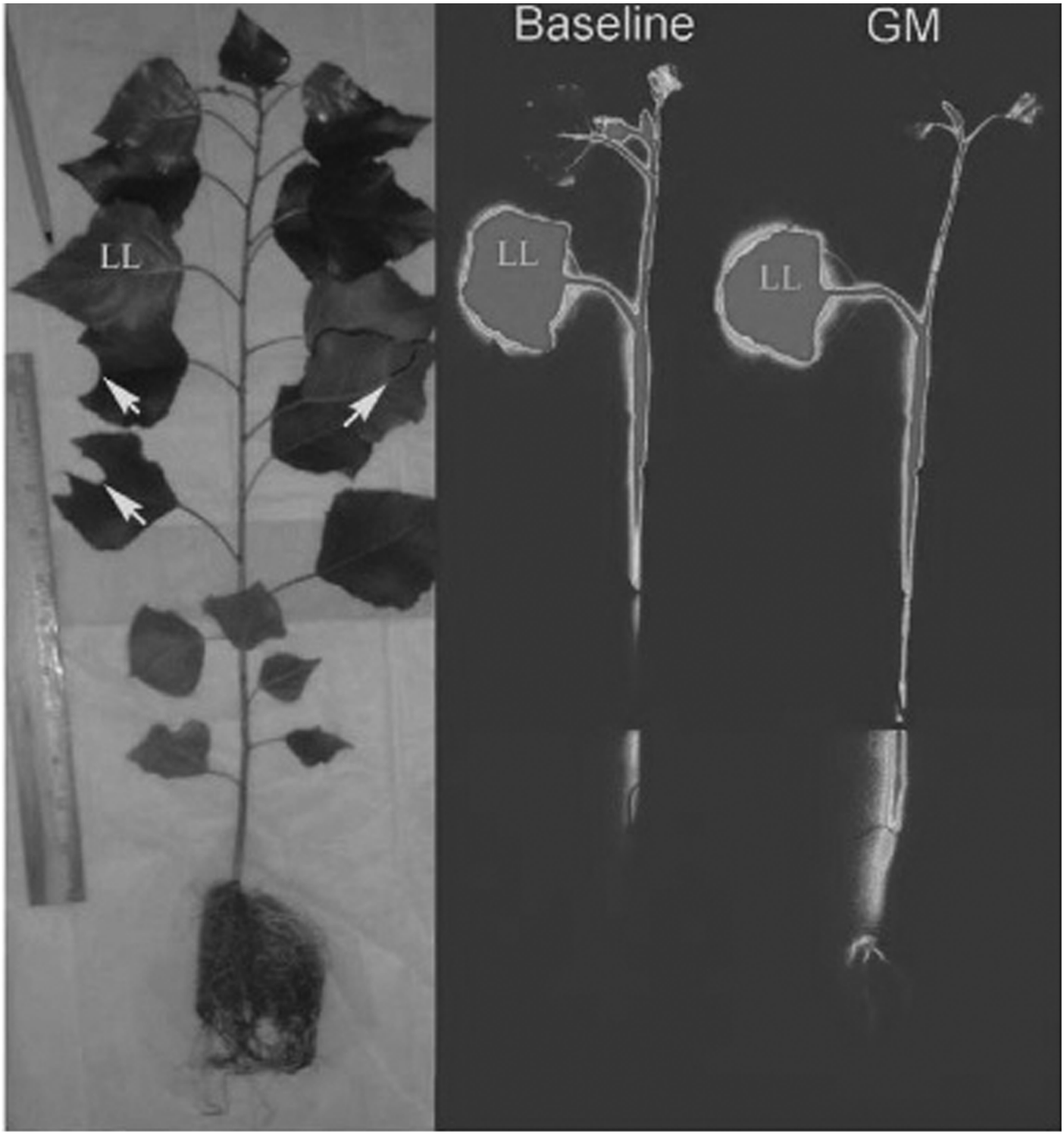
One issue the team faced was the fact that ammonia, though usable by plants, is toxic in large amounts. They had to produce the compound with high levels of radioactive nitrogen in order to have a useful tracer effect without killing the plants. The researchers also compared plants with ammonia to plants not exposed and verified that plants weren't affected by the small amounts of ammonia they did need to use.

Once the toxicity of their new method was accounted for, Orians' team wanted to find out what would happen to the nitrogen within a plant as its defenses were triggered. The organisms they investigated were *Nicotiana tabacum*, the tobacco plant farmed for most of today's tobacco products, and *Solanum lycopersicum*, a delicious organism also known as the tomato plant.

Orians and colleagues started off by exposing the plants to a chemical called methyl jasmonate, which tricks plants into thinking they are under attack. The team then observed that, compared to undisturbed tomato plants, these treated plants were putting the radioactively tagged nitrogen in different places: the amount of nitrogen being exported from the leaves went up by almost a factor of two, and the amount going into the roots went from about 40% of the total to about 60% [5]. Carbon was also traced in the tomato plants, using radioactively marked carbon dioxide in a similar setup. Orians' team found that photosynthesis (the conversion of CO_2 into sugar) slowed after each "attack," and they found that carbon-containing compounds were also shunted downwards towards the roots. The change in carbon allocation, though, was not as severe as the reallocation of nitrogen [5].

The high rate at which nitrogen exits the leaves may change carbon:nitrogen ratios, favoring the production of compounds that deter herbivores. In tobacco, the simulated attack directly triggered changes in metabolism, increasing production of certain amino acids (nitrogen-containing molecules) even as the total amount of nitrogen processed stayed constant. This is known as "partitioning"—changing the distribution or allocation of a resource. The authors hope to extend this new knowledge of metabolism changes and find out how it leads to compounds like nicotine, which are crafted to ward off predators.

The transfer of materials may also be a way of guarding resources until herbivores move on. "After damage," the authors say, "plants often rely on stored reserves to compensate for the tissue loss," [5]. The authors say that other studies have also distinguished between fine roots, which take up water and nutrients, and taproots, which store nutrients [6]. They have found that nutrients are also shunted away from fine roots and towards



This graphic, produces using methods similar to the ones in this article, shows the position of marked carbon-containing molecules with (GM) and without ("baseline") herbivory. After herbivory, the root system shows more carbon entering, and much less carbon goes upwards from the marked leaf (LL). Image from Babst et al, 2008, "Lymantria dispar *herbivory induces rapid changes in carbon transport and partitioning in* Populus nigra." *Reproduced with author's permission.*

taproots, which strengthens the storage hypothesis. This temporary storage of resources in known as sequestration.

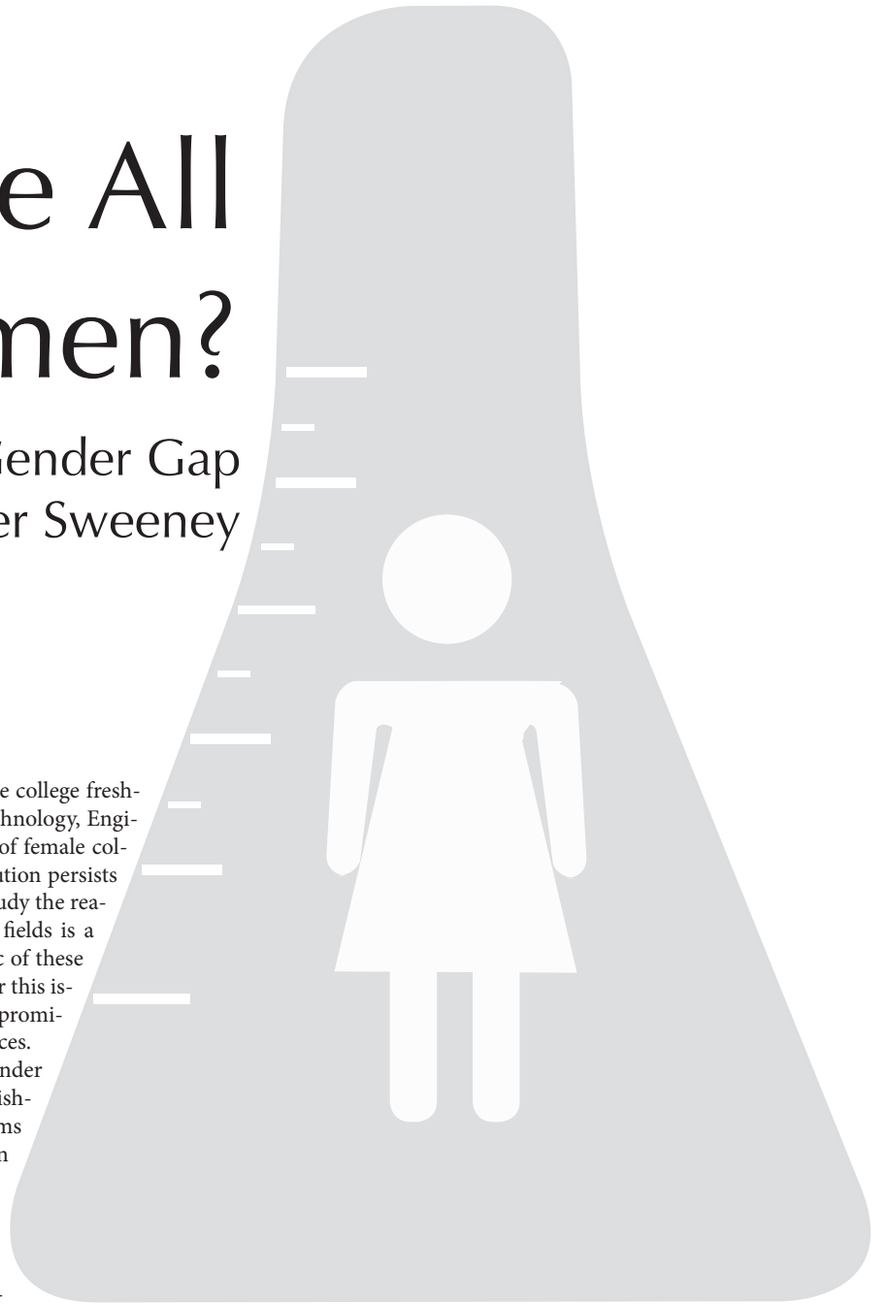
Sequestration is not without costs. In light of the distressed plants' missed opportunities for growth and development, an earlier paper that Orians coauthored is entitled "Herbivore-induced resource sequestration in plants: Why bother?" Indeed, each gram of sugar in the roots denies the top leaves needed resources and prevents them from enlarging and generating more sugar. Another important note the authors make is that, in the case of diseases and herbivores that attack roots, the sequestration strategy can backfire and make the plant more susceptible.

Professor Orians considered working in agriculture, saying he has "always been focused on plants." His PhD is in entomology (insect science), but his aim at the time was primarily to see how insects interacted with their food sources, often crops and always plants. The question he asked in this recent work was "Is this (sequestration) another way that plants defend themselves?" The hope is that a better understanding of plant defenses will lead us to better crops, better pest control, and more food for us humans.

Story by Eric Kernfeld, a freshman majoring in biology and mathematics.

Where are All the Women?

Examining the STEM Gender Gap with Dean Berger Sweeney



In 2006, according to the NSF, 29 percent of male college freshmen intended to major in a STEM (Science, Technology, Engineering, and Math) field while only 16 percent of female college freshmen intended to do the same [1]. This distribution persists at the professional level (refer to Figure 1). I set out to study the reasons for the under-representation of women in STEM fields is a complex and sensitive proposition. To discover the logic of these statistics, I sat down to discuss three studies that consider this issue and possible solutions with Dean Berger Sweeney, a prominent neuroscientist of the Tufts School of Arts and Sciences.

One major factor thought to contribute to the gender gap is bias against female researchers in hiring and publishing. A recent article on the studies of Ceci and Williams found that conscious bias in hiring and publishing in STEM fields has decreased dramatically, and that acceptance rates for papers by men and women with similar resources are roughly equal [2]. Ceci and Williams argue that women in STEM fields have fewer resources than men. Women hold disproportionately more teaching-intensive and part-time positions, which gives them less access and funding to perform research. They attribute the gender gap to three main factors: women's fertility and lifestyle choices, women's preferences for working with "people" rather than "things," and ability differences, especially in the high-tail of mathematics scores. Female academics are expected to perform their most intense research, and go through the tenure process, at the same age they are having children. They argue that only through offering more flexible options for those with children, like the ability to pause the tenure process and the possibility of working part-time while children are young, will we begin to see more gender parity in the STEM fields.

Dean Berger Sweeney, though mentioning much of the article rang true personally, offered some caveats on the study, expressing her opinion that it "may have simplified the problem too much." She said that while she did not personally face a lack of resources, nor did raising a family negatively affect her career, she has experienced this bias in more subtle ways. "When I was interviewing at a very, very prestigious research institution, one of the faculty said [referring to a pregnant postdoctoral researcher], 'My goodness, don't people know that they can't be pregnant on tenure track and expect to have a job?' Was any of this about me? No, but I'm sitting there in a job interview with two or three males and this is the subject of the conversation." After this interview in 1990, she chose to work at Wellesley, an undergraduate liberal arts college for women. She explained, "The number of articles I had written, the funding I had gotten as a graduate student, would have put me on a trajectory to be at a research university… if I had chosen that route." She stressed that this was a personal choice, and asked, "Did I choose that based on how I wanted to practice my science?"

Ability differences in math are other possible causes of the gap that Ceci and Williams put forth, an idea that Janet Hyde and Janet Mertz thoroughly examined in an earlier paper [3]. Hyde and Mertz consider the evidence that Ceci and Williams focus on: the male to female ratio of students with SAT-Math scores at the top 0.01% has remained a stable 4:1 since the mid-1990s. Dean Berger Sweeney pointed out a major flaw in this evidence: "You take … boys and girls, and you give them a test of mathematics, and you're testing their ability at that point in time. You really are not accounting for any gender biases that might have occurred up to that point to create the differential that we see." She also discussed the cultural factors that affect women's feelings about STEM. She mentioned,

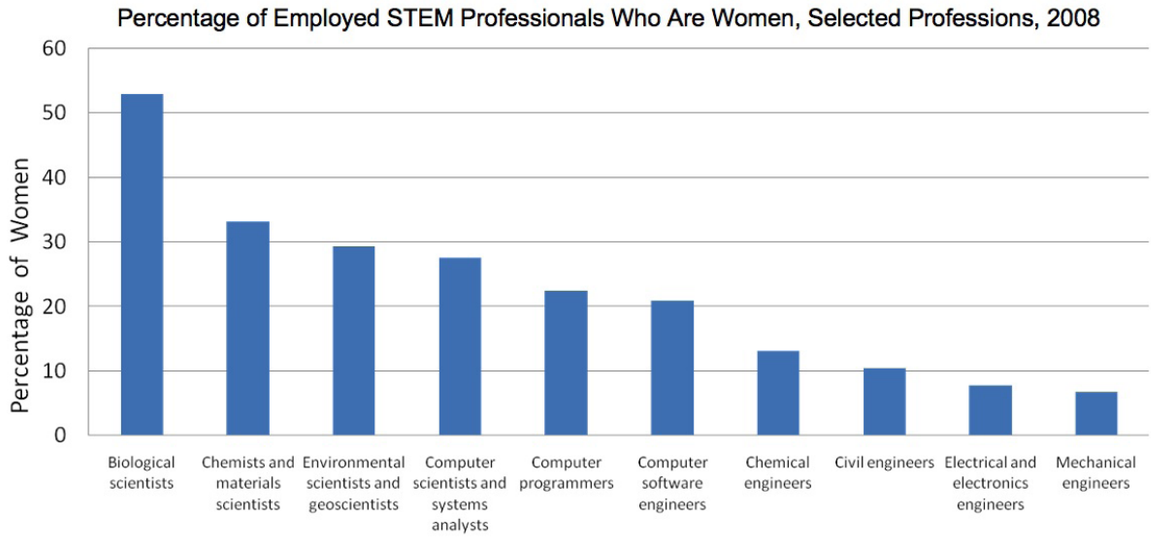


Figure 1. Percentage of employed STEM professionals who are women, 2008 [1]. Data from U.S. Department of Labor, Bureau of Labor Statistics, 2009, Women in the labor force: A databook (Report 1018) (Washington, DC), Table 11.

"When I was at Wellesley, there was a Barbie that said, 'Math is too hard!' We actually wrote a letter of protest… Little things like that can make big differences to girls." Hyde and Mertz agree that this gender gap for high achievement in math in the US is due to socio-cultural reasons. They found that the mean gender difference in scores on the Second International Mathematics Study (SIMS) significantly correlated with measures of gender inequality in a country.

Even if we take this study of SAT-M scores at face value, as Ceci and Williams do, can we say that it is these gifted students that go on to work in STEM and cause the gender imbalance? Hyde and Mertz note that less than one-third of college educated white US males in the STEM workforce scored higher than 650 on the SAT-M test. No matter what the cause of the distribution of SAT-M test scores, it is not a main cause of the large gender gap in the STEM fields.

So what can we do to help close the gender gap, and ensure that women who are interested in STEM are encouraged to pursue their academic interests? In a series of studies performed at U Mass Amherst, Stout, Dasgupta, Hunsinger and McManus examined the effect of stereotype threat on female engineering students and ways to mitigate this effect [4]. Stereotype threat is when awareness that one faces a negative stereotype causes them to fear others judging them as fulfilling that stereotype. In these studies, Stout et al explored the idea that having female role models can fight this effect for female STEM students. They found that exposing female engineering students to a female math graduate student increased their own identification with STEM fields, yet did not change their overall view of STEM as associated with males. It also led these students to attempt more problems on a difficult math exam and rate their mathematical proficiency as higher than students exposed to a male math graduate student.

Stout et al. also studied the effect of having a female mathematics professor versus a male mathematics professor on a group of engineering students in different sections of the same mathematics course. Having a female professor increased female students' feelings of proficiency, and had no effect on male students' feelings of proficiency. It also correlated with an increase in class participation from female students, while female students with a male professor decreased their interaction with their professor. Dean Berger Sweeney generally agreed with the study's conclusions on the importance of role models, explaining, "I think there is a considerable amount of data that having role models does make a difference… it's not the sole factor, it's not the only factor." Commenting on her experience as an undergraduate at Wellesley College, she continued, "I saw so many women who were scientists and who were teaching me that I couldn't even imagine that my gender would prevent me from being a scientist."

Though increasing the amount of contact female students have with female STEM professionals and implementing more family-friendly policies may help close the gap, what becomes clear from these studies is that there is no easy solution. According to Ceci and Williams, we can no longer pin the gap on gender bias in publishing and hiring, but must look at the web of cultural and social factors that motivate women's career choices and identification with STEM. Dean Berger Sweeney summarized the studies: "It's such a complex issue that none of these are fully explaining for each and every single woman what it feels like and why they either do or don't stay in science. But I would say that we had certainly better figure this out. With the majority of students in higher education now being women, if you can't figure out ways to make this more appealing broadly, I think we're just not going to have the number of scientists that America needs to support future innovation."

Story by Lauren Wielgus, a senior majoring in Physics.

"With the majority of people in higher education now, students being women, if you can't figure out ways to make this more appealing broadly, I think we're just not going to have the number of scientists that America needs to support future innovation."

Photo Courtesy of Getty Images.

A LOOK INSIDE GEOLOGY

Uncover The Ins and Outs of Tufts' Geology Department

While searching for answers about Earth's past, dynamic present and uncertain future, the geologists in Lane Hall remain intent on sharing and discovering with students. Take Professor Grant Garven, who dedicates an entire area of his work to creating an outdoor laboratory for students to study groundwater hydrology right on campus. This laboratory is the Geo Jumbo Array, a collection of monitoring wells bored at various locations around campus that Garven and his students use to measure geophysical properties, map groundwater flow, and take water samples for chemical analysis. Professor Garven, a groundwater geologist, said he developed this "one of a kind facility" in the hopes of sharing a real world understanding of course material with students. "I thought it would be more rewarding…to have an outdoor laboratory where I can teach a class," Professor Garven explained. In a department known for its field trips and hands-on learning style, students can now get what Garven considers "valuable training" in hydrogeology without leaving campus.

A 700-ft deep geothermal well, bored this winter, is the most recent addition to the array. By logging geophysical properties and instrumenting the borehole with pressures and temperature sensors, Garven and his students will create a hydrograph, or a time series of the data they collect over the next decades. With this, Garven hopes to show his students that "water is a sensitive measure," that reveals important information about seasonal changes in geothermal and pore pressure inside Earth's crust.

It appears to be a common theme in the Geology Department that faculty work extends far beyond one area of research. In addition to editing a collection of articles, Frontiers in Geofluids, published as a book in February, Garven is collaborating with Dr. Meg Tivey at Woods Hole Oceanographic Institute to study black smokers, hydrothermal vents at mid-oceanic ridges. This National Science Foundation-funded study uses mathematical models of reactive fluid flow to explore the physics and chemistry of these vents, which are home to a variety of organisms. The study may help develop an understanding of how life begins in extreme environments. And, in additional studies funded by the Department of Energy, Garven is looking at faults in California and how they affect fluid flow. This work has many environmental implications for understanding the hydrogeology of carbon sequestration, hydraulic fracturing of gas-bearing shales, and the origin of submarine gas hydrates.

Developments in faculty research like the Geo Jumbo Array are contributing to course growth at Tufts. Professor Anne Gardulski, Department Chair, said, "We're really pleased that we are developing practical and fundamental courses in groundwater studies." Gardulski added that a strategic planning meeting, to take place in May, will enable the department to evaluate their missions and goals and hopefully work towards future initiatives.

For her research, Gardulski, who has previously focused on marine geology, is currently studying sedimentology and stratigraphy of continental deposits, with fieldwork in Arizona and New Mexico. Her goal is to gain an understanding of the area's past by studying Triassic period rock there. "I'm trying to reconstruct the ancient environments that these sedimentary rocks represent," Gardulski explained.

To do this, she often combines her studies with the work of Jacob Benner, an ichnologist, or paleontologist who specializes in the study of trace fossils. Students have also joined Gardulski and Benner to the Southwest to conduct research and experience the "little wow moments" that Gardulski finds rewarding.

A large rock slab containing a multitude of visible fish fossils stored now in Gardulski's office is the result of one of these moments. The rock, cracked open by one of two students working with Gardulski and Benner in a remote canyon in Arizona, was the first fossil evidence found on that trip. From the fossils, the group was able conclude that standing water was once present in the area. Gardulski said that in these instances, the biggest reward is "the intellectual challenge and satisfaction of figuring something out."

Gardulski added that a strategic planning meeting, to take place in May, will enable the department to evaluate their missions and goals and hopefully work towards future initiatives.

Gardulski also shares "neat discovery times" with students on teaching field trips she co-leads with Benner. This winter, a group of students travelled to Arizona and New Mexico for a trip that "highlights billions of years of geologic history," according to Benner. Next spring, students will travel to Utah to observe faults and folds in places like Arches National Park and Canyonlands. Gardulski described, "It's just a wonderful natural laboratory for teaching." Even in the classroom, Gardulski

aims to share the rewards of discovery with students, integrating sediment cores and other finds from her research into the courses she teaches.

But with the rewards do come challenges. Space and time in the geology department is limited, especially considering the commitment the faculty has to students. The extra time the department puts in for their students may take up valuable research time, but, as Gardulski explained simply, "We like teaching."

Assistant Professor Molly McCanta must balance not only teaching and research time but also a variety of research topics, both terrestrial and extraterrestrial. With funding from the NASA Lunar Advanced Science and Exploration Research program, McCanta is working with colleagues at MIT to study the differentiation of the lunar interior. Part of the study will try to determine how the presence of water within the moon during early lunar history affected how the moon evolved. At MIT, McCanta subjects samples to pressures and temperatures found in the lunar interior and analyzes the minerals found throughout the resulting crystallized samples.

McCanta also conducts research on Martian meteorites. The analysis of Martian meteorites on Earth provides expansive chemical information to compliment data from spacecraft such as NASA's Spirit and Opportunity Mars Exploration Rovers. According to McCanta, these spacecraft provide bulk chemical data and a perspective of where on Mars rock units and geologic features are located. Using this perspective along with the more extensive chemical analysis of meteorites, researchers like McCanta hope to compose a complete picture of Mars.

Chondrites, meteorites that have never been re-melted nor subjected to geologic processing and therefore "represent the earliest history of the solar system" are another focus of McCanta's work. Studying chondrites can reveal information about the history of the entire solar system. Comparison of earth materials with these "pristine" meteorites may also help shed light on Earth's geologic history, according to McCanta. Even comparison to other planets, which may have undergone significant geologic processing, help scientists study Earth. Because other planets may have differentiated in a manner similar to the way Earth did, McCanta explained, studying these bodies "gives us a chance to understand our planet a bit better as well."

Professor Jack Ridge is studying geologic processes a little closer to home, in New England's Connecticut River Valley. Through the Jumbo Varve Project*, funded by the National Science Foundation, Ridge began work to improve the chronology of glaciation and past climate in New England based on the study of varves. Varves, which are annual layers of sediment, are analogous to tree rings, providing a highly detailed record of sedimentation for an area. The varves that Ridge examines were formed in glacial lakes. Studying varve samples, collected from outcrops and subsurface cores, reveals information not only about seasonal differences in the region but also about the presence of organisms in the area, the area's climate history, and the record of human inhabitance of the region.

The varve project works to match individual varves regionally to establish a varve chronology, which is an annual record of varve deposition that currently spans about 5700 years of correlated varves. Matches are determined based on similar patterns of changes in thickness for different varves. Ridge appreciates the excitement of finding such matches that his students have been able to experience while working on the Jumbo Varve Project. In 2008, a significant step in matching was made, as students were able to assist in bridging the Claremont Gap, a historic gap in regional varve sequences in New England. The project has also calibrated the varve chronology to calendar years using radiocarbon ages of plant fossils found in the varves. This places the varve chronology at 18.2-12.5 thousands of years ago, right in the middle of the collapse of the last major ice sheet to cover North America.

Seasonal differences are clear in the varves Ridge has collected. Layers of finer sediment settled during non-melt periods (winter months) and are distinct from the layers of coarser particles that settled during times of melting (summer months). But differences in sediment thickness over decades are also visible. Differences over decades provide evidence about climate change when the last ice sheet receded from New England, a time that Ridge described as having a very unstable climate. Similarities in New England varve records and climate records from Greenland and Europe indicate climate connections across the entire North Atlantic region during this period. Attempting to explain what caused mean annual temperatures to jump five to ten degrees Celsius at numerous times during this last climate change is one goal of the research.

Although understanding climate patterns of the past may not directly aid the modeling of current or future climates, a grasp on climate connections may help focus this study. Ridge explained that today's climate is stable compared to the ice age climate, making comparison between the two time periods difficult. However, understanding cause and effect relationships may be useful for making predictions about the climatic effects of events like the melting of the Greenland ice sheet. Ridge explained, "There can be real abrupt changes and it's important to understand what triggers them." Understanding past climates helps us "realize the types of things we are going to have to get a handle on to study modern climate, and it places a geologic perspective on the operation of Earth's climate system."

The varves have also been a source of significant paleontological discovery. Evidence of organisms is found in fossils throughout the varves. Jacob Benner has recently been working with Ridge to study trace fossils in the varves. Trace fossils, or fossilized tracks, trails, and burrows, are formed "just like a foot print on a beach," described Benner. In Lake Hitchcock of the Connecticut River Valley, fossils provide evidence of the first fish to inhabit the valley following the last glaciation, some of which are comparable to modern species, such as Arctic Charr and sculpins. Ridge says that, "prior to working with Benner I had always thought that few organisms, other than a few worms and insect larvae, could tolerate the cold and turbid conditions of New England's ancient glacial lakes. This definitely changes a long standing paradigm in glacial geology."

Benner's larger project examines trace fossils of much older organisms from a 315 million year old Pennsylvanian rock formation in Massachusetts. Currently, Benner is working with students to analyze thousands of samples of early terrestrial insects and amphibians from this formation. Benner said of his research, "it's a lot of field work, and you don't always get rewarded, but when you do, it's a thrill."

Perhaps one of this project's most thrilling discoveries was that of a fossil of an insect body that may represent the basal group of today's modern mayfly. Finding a fossil of the body of a flying insect and not just of its fossilized wings, is a rare occurrence. This unique find is just one of the many tangible geologic discoveries developing at Tufts. *Story by Catherine Hoar, a sophomore majoring in Environmental Engineering.*

**The Jumbo Varve Project officially ended last April. The North American Glacial Varve Project can be found at http://geology.tufts.edu/varves*

A 700 foot deep geothermal well was bored on Tufts' campus this winter.

One of several monitoring wells bored for the Geo Jumbo Array.

Better Place seeks to change the way we think about electric vehicles. Their innovative model is already meeting success in Israel and in effect, is putting on an...

Electric Show

Can you run a country without oil? Better Place, an electric vehicle (EV) infrastructure company founded in 2007, seeks to prove the answer to this question is 'yes.' Better Place will launch their electric vehicle infrastructure in Israel in late 2011 and is planning to expand their network to Denmark, Hawaii, and Australia shortly thereafter.

Challenges of Electrification There are two critical problems that have impeded the adoption of electric vehicles. First, expensive batteries place the vehicles well above the price at which widespread market adoption would be possible. Better Place is founded on the premise that electric vehicle batteries should be part of the electric network that powers the vehicle, not part of the vehicle itself. This approach makes electric vehicles more economically viable because the largest cost, the battery, is removed from the equation. Instead, consumers pay for miles in the form of electrons, much as we purchase miles in the form of gasoline currently.

Second, electric vehicles have significant range constraints. While over 90% of travel requires less than 100 miles of range, longer trips would require recharging the vehicle's battery. By separating battery ownership and car ownership, the Better Place model is able to use battery swap

Photo Courtesy of Better Place.

By delivering the network and services, Better Place makes an electric car affordable and efficient.

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stations instead of battery recharging stations as a range extension mechanism. The Better Place battery swap stations take approximately one minute to replace a spent battery with a fully charged battery, as compared to the hours it might take to charge a battery during a lengthy road trip. The Better Place model reduces the time needed to replace a vehicle's battery to the time it takes to fill up a gas tank. For shorter-range travel within 100 miles, no battery swap is required. Instead, car owners simply plug their vehicle into a residential charging station overnight and it's fully charged by morning.

Energy Production

Critics of electric vehicles often cite the fact that EVs don't solve our reliance on oil or other environmentally harmful forms of electricity generation because the electricity for the vehicles must still be generated by coal, gas, nuclear, or other power sources. Yet, shifting oil use and greenhouse gas generation from vehicles to power plants makes petroleum reliance and pollution far easier to regulate and control. This shift also centralizes the generation of greenhouse gases around power plants, an improvement to the distributed nature of the pollution generated by million of combustion engines operating across the nation. The Better Place model also promises to make renewable energy projects more productive because each vehicle in the Better Place network will function as storage for excess electricity generated by renewable sources during off-peak periods so that energy can be utilized during peak periods. Off-peak storage of renewable electricity is currently one of the largest barriers to renewable energy projects across the globe. It is believed that shifting to a EV network such as Better Place could serve as a catalyst for transitioning countries over to renewable sources of energy.

An Attractive Energy Cost Model

Among the most appealing aspect of the Better Place model is its economics. The cost of the vehicles is cheaper than or competitive with existing combustion engines. While current electric or hybrid vehicles are often purchased by ideological buyers, the vehicle cost structure of Better Place's model will allows widespread adoption of electric vehicle technology among more price sensitive consumers.

The cost per mile in the Better Place network is estimated to be about $.09. Currently, Americans pay about $.12 per mile and most other countries around the world pay close to double that number. Further, while global oil costs go up as usage increases, the cost per mile declines over time as because batteries become more efficient. This declining cost curve makes Better Place an even more attractive solution to the global reliance on oil.

An Amazing Story

The story of Better Place's founding is certainly unique. The founder, Shai Agassi conceived of the idea after attending the World Economic Forum in Davos, Switzerland in 2005. Previously, Agassi had been a serial entrepreneur, ultimately founding a software company that was acquired by enterprise software giant SAP. Through the acquisition, Shai became the President of SAP's Products Division. In 2007, at the age of 36, he was presumed to be the successor to the CEO, who was planning on stepping down in 2007. At the conference, Klaus Schwab, the Chairman of the World Economic Forum, told those in attendance: "You have a responsibility to figure out how you can use your skills and talents to make the world a Better Place by 2020" Over the next year, Agassi researched the global dependence on oil and developed a 38 page white-paper with what he thought was the solution. He circulated this paper to government officials who he had met through his work with SAP and ultimately received interest from Shimon Perez, the Prime Minister of Israel. Perez encourage Agassi to pursue the solution he set forth in the white paper and offered up Israel as a place to pilot the idea. A few weeks later, Agassi quit his job at SAP and raised 200 million dollars over the next six months in seed capital to found Better Place. Since then, the company has raised close to 1 billion in investment to build out its infrastructure in Israel, Denmark, and other countries around the world. To find out more about Better Place, visit their website at www.betterplace.com.

Story by Dan Slate, a senior majoring in Biology.

The Evolution Debate

An American Phenomenon

Charles Darwin published On the Origin of Species in 1859 with overwhelming evidence for his theory of evolution. This evidence has only increased in the intervening 150 years as generations of biologists have expanded the theories of evolution and natural selection. Yet today, even in the face of such profound evidence, a large portion of the United States is still unconvinced—a sharp contrast to Europe, where the majority accepts evolution. Why, in this age of science and technology, does much of the public remain unconvinced by what is conceivably the strongest, most fundamental biological theory?

Perhaps the oldest and most well-known opposition to evolution is rooted in religion. From the onset, religious groups opposed Darwin's groundbreaking theory because it conflicted with their vision of humanity's origin on Earth. Lately, many religious groups (most notably the Catholic Church) have declared that the theory of evolution does not conflict with their beliefs. Still, many fundamentalist groups continue to resist evolution because of their literal interpretation of Genesis or some other dogmatic objections. Such groups attempt to mold the public school system to fit their beliefs by vehemently opposing the teaching of evolutionary theory in public schools or demanding that other "theories" of our origin be taught alongside it.

A 2006 study by Jon Miller, Eugenie Scott, and Shinji Okamoto discovered that religious belief strongly influences an individual's attitude toward evolution in the United States. This influence was found to be nearly half as strong in a survey of nine European countries (Britain, Germany, France, Italy, Spain, the Netherlands, Denmark, Austria, and Poland) [1]. According to Miller, Scott, and Okamoto, a likely explanation for this discrepancy is the difference in American Christian and European Christian interpretations of Genesis. Fundamentalists in the United States interpret Genesis as a literal account of life's origin, while their protestant counterparts in Europe view Genesis as metaphorical and find no major contradiction between faith and evolution [1]. Patrick Forber, an Assistant Professor in Tufts Philosophy Department who specializes in the philosophy of biology, expressed a similar opinion: "The importance of religion to the American identity […] play[s] a role in the increased opposition to teaching our best scientific theory of biological origins in high school."

Religious belief strongly influences an individual's attitude toward evolution in the United States, an influence that was found to be nearly half as strong in a survey of nine European countries.

Opponents of evolution repeatedly insist that theories such as creationism and intelligent design be accorded equal resources in high school classrooms. In 2004, the Dover Area School District school board of Dover, PA introduced a curriculum that included intelligent design before it was declared unconstitutional in the court case Kitzmiller v. Dover in 2005 [2]. According to Patrick Forber, belief in intelligent design and creationism among the opponents of evolution "is bound up with their view of humanity and their ideas about our place in the world. When you look out and you see beautifully designed things that were purportedly designed by natural selection, there's an intuition that that's just not possible." Groups that continue to oppose evolution in the face of overwhelming evidence threaten our educational system. However, religion isn't the only fuel feeding the evolution debate in America.

It's hard for us to imagine intricately, beautifully designed organisms evolving by this really simple mechanism because I think we have a hard time grasping the timescales involved.

Another important factor in the distrust of evolution is a misunderstanding of the theory itself. In a 2004 study, Randi Trani linked Oregon high school teachers' depth of understanding of evolution to the effectiveness or ineffectiveness of their presentation of evolution in the classroom [3]. According to Trani, the presentation of evolution by these teachers with limited knowledge of evolution "most probably would be fraught with inaccuracies, including the presentation of creationists' arguments as valid scientific principals due in large part to their poor understanding of the theory of evolution." Sixteen percent of teachers fit this description. Though this percentage may appear trivial, when one considers the student turnover rate, this sixteen percent of teachers have access to a vast number of students who will graduate with a minimal to poor understanding of evolutionary theory [3].

Patrick Forber argued that the main difficulty with understanding evolutionary theory is in comprehending the vast, almost intangible amount of time evolution has been acting to create the life we see today. We can

understand the mechanisms of evolution over a few generations, "but to really scale them up, and think in the broad scope of millions or billions of generations is difficult for us… so it's hard for us to imagine intricately, beautifully designed organisms evolving by this really simple mechanism because I think we have a hard time grasping the timescales involved."

A prolific misunderstanding of the word "theory" poses a growing problem to proponents of evolution. The meaning of "theory" in scientists' and laymans' vocabularies differs in a crucial aspect. As Randi Trani puts it, "while science understands that a theory, like evolution, is a well-substantiated explanation of some aspect of the natural world, the public understands a scientific theory to mean a guess, a hypothesis, or lack of understanding" [3]. a crucial difference in the meaning of this word is responsible for a large component of the anti-evolutionists' argument. They insist that evolution has not been, and never will be, proven. Theories may only be supported by the compiling of massive amounts of evidence, and while evolution can never be proven outright, scientists have collected overwhelming evidence in support of the theory of evolution.

However, the scientific community is not without fault. Patrick Forber raised an issue with the presentation of evolution by many prominent scientists. Richard Dawkins and likeminded individuals have packaged evolutionary theory with atheism, giving the impression that theism and evolution are mutually exclusive principles. But Forber explains that this is not true: "there's nothing necessarily incompatible with accepting evolution by natural selection and theism." Many scientists and biologists are atheists, but there are also many theists among their ranks. Associating evolution and atheism only fuels religious objections to the theory by presenting the two as incompatible.

The anti-evolutionary movement is one fueled largely by religious motivations and misconceptions. This debate isn't likely to go away soon: evolution remains our strongest explanation for the origin of the species on Earth today and it isn't likely to fade away due to pressure from any group. While it is possible to deny the truth and attempt to suppress it, evolution can never be totally extinguished from the minds of devoted scientists. Most likely, as our educational system improves and understanding of evolution permeates the American public, the issue will fade into obscurity.

Story by Sam Bashevkin, a freshman majoring in Biology.

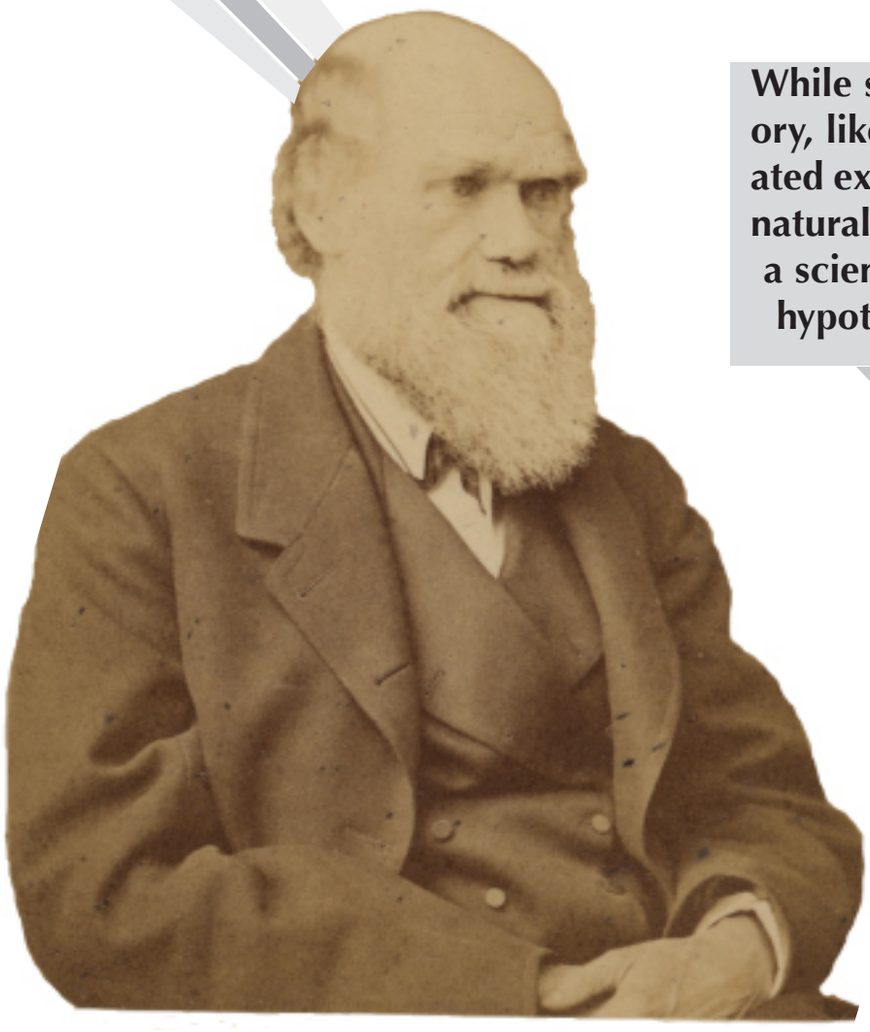


Photo Courtesy of Getty Images.

While science understands that a theory, like evolution, is a well-substantiated explanation of some aspect of the natural world, the public understands a scientific theory to mean a guess, a hypothesis, or lack of understanding.

Stem Cell Therapy Promises to Change The Way We Think About Broken Bones

Undergraduate Justin Pick seeks to use growth factors to enhance the production of bone tissue in osteoblasts

The next major medical innovation of the twenty first century will likely be in the field of tissue engineering. Researchers are now able to grow organs in the laboratory that will one day be used to replace diseased or damaged tissue in patients. The process starts with the isolation of stem cells—but not the embryonic cells commonly discussed in the media. Though embryonic stem cells show the greatest potential for cell differentiation, these cells pose difficult problems besides the well-publicized moral issue. For instance, the cells may not be immunologically compatible with the individual, and could be rejected by the patient receiving the cells. Embryonic stem cells may also form malignant tumors in the sites they are implanted. Depending on the organ system, other stem cells naturally occurring in the body can be used that don't have these problems – like mesenchymal stem cells. Mesenchymal stem cells are produced in the bone marrow and can differentiate into bone cells, fat cells, or cartilage cells. There are many other types of stem cells used to engineer tissue of different cell types, but mesenchymal stem cells are one of the most popular choices for bone tissue growth and the basis of the research discussed here.

My research tries to create bone by imitating the natural bone healing process in the lab. Specifically, I'm focusing on the ability of mesenchymal stem cells to differentiate into bone forming cells called osteoblasts and construct bone. The first step in the healing cascade is the production of a swollen bloody mass called a hematoma. The hematoma contains a cocktail of growth factors that guide the healing process. One of the most important primary processes is the production of blood vessels (vasculogenesis) to bring oxygen and nutrients to the injured area. Vascular Endothelial Growth factor (VEGF) induces vasculogenesis and reaches its peak concentration within a week following the injury. As vasculature (the system of blood vessels) is growing, mesenchymal stem cells are also slowly differentiating into osteoblasts in response to the growth factor BMP-2 (bone morphogenic protein-2). BMP-2 is released slowly and reaches its peak release a few weeks after the injury. Research has shown that VEGF and BMP-2 play large roles in the differentiation of osteoblasts, and some research has shown that the two growth factors act synergistically to affect bone growth.

I hypothesize that the controlled release of VEGF and BMP-2 from the scaffold in a manner similar to natural conditions will up-regulate bone formation (osteogenesis). I have created a silk sponge that will store the VEGF, BMP-2, and mesenchymal stem cells. The sponge has been designed to secrete most of the VEGF over the course of a week and most of the BMP-2 over the course of 3 weeks to imitate physiological conditions. I am comparing the proliferation, differentiation, and bone content of the cells exposed to neither, one, and both growth factors and looking for a synergistic effect. One day bone fractures will heal considerably faster because of great advances in stem cell therapy. *Story by Justin Pick, a senior majoring in Biology.*

Justin Pick works under the hood. Photo courtesy of Noah Paulson.

Sonoluminescence

Sonoluminescence is when sound is used to produce light and heat from bubbles.

Imagine holding a stereo next to a bubble bath and the resulting sound making the bubbles glow. The actual effect requires more sophisticated equipment than a stereo, but the basic idea is the same. Sonoluminescence is when sound is used to produce light and heat from bubbles.

This phenomenon was first discovered in 1934 by H. Frenzel and H. Schultes at the University of Cologne in Germany. They were researching underwater acoustic radar and observed a chaotic display of flashing bubbles when experimenting with ultrasonic frequencies . Ultrasonic frequencies are sounds that are too high-pitched for people to here, with frequency levels of at least 20 kHz. Minimal research was done until the late 1980s, though, as the results attained by Fenzel and Schultes were difficult to repeat consistently. Understandably, the usefulness of glowing bubbles was probably not deemed very high.

From 1988 to 1995, knowledge of sonoluminescence expanded. Researchers made a number of observations: the emission of light (a bright blueish-white) corresponds with a sharp decrease in bubble size, the length of the flash is on the order of picoseconds (1 picosecond = 1 trillionth of a second), and the time between flashes depends upon the sound frequency1(1). The bubble is also known to condense to one millionth of its original volume. This collapse generates an incredible temperature differential within the bubble, with recorded temperatures exceeding 130,000 ˚F . In comparison, the surface of the sun is only a paltry 10,000 ˚F .

This collapse generates an in credible temperature differential within the bubble, with recorded temperatures exceeding 130,000 ˚F

There is still work to be done, though. The biggest question plaguing scientists is why the light actually occurs. The emitted light exists primarily in the ultraviolet range, and the energy responsible for the temperature change cannot fully explain the light. Gathering data is difficult given the tiny size of the bubble (less than a millimeter in diameter) and the brevity of the pulses3. A number of explanations are being debated at the moment, even nuclear fusion , but it is too soon to say whether or not the world of tomorrow will run on bubbles.

Story by Jackson Dolan, a senior majoring in Mechanical Engineering.

Tufts Ph.D, Huai-ti Lin, Examines Bird Flight In Order To Assist Plane Aerodynamics Research

Yet to turn 25, a freshly minted Tufts Ph.D Huai-Ti Lin is now taking on new challenges at Harvard as a postdoctoral fellow studying animal flight biomechanics and navigation. His current project aims to apply knowledge of bird flight to developing an autopilot system for unmanned aerial vehicles (UAVs) moving at high speed through cluttered environments.

Huai-Ti trained in the Tufts biology Ph.D program while doing research at Tufts engineering facilities. Originally from Taiwan, he graduated from the University of Massachusetts Amherst in 2006 with a major in physics and a minor in biology. Huai-Ti was then recruited to Tufts as a Provost's Fellow and studied caterpillar locomotion with Professor Barry Trimmer. Huai-Ti also developed several soft-bodied robotic platforms during his time at Tufts as part of his research in soft-bodied animal biomechanics.

Currently, Huai-Ti's research at the Harvard Concord Field Station involves analyzing how birds navigate through forest environments at high speed. Huai-Ti and others send pigeons through artificial indoor pole forests and track the pigeons' body and head movements in 3D. This experiment, according to Huai-Ti, is designed to "[tease] out the flight planning behaviors in birds by challenging the birds with difficult obstacle courses." In order to characterize pigeon's flight, the Harvard researchers outfitted the bird with various telemetry equipments. Huai-Ti fashioned a cap with a camera on top and strapped this to the pigeon's head for in-flight videography. By aligning the camera with the bird's frontal vision, the researchers can extract visual information that might be relevant to the bird during flight. In addition to the head mount camera, several sensors including an inertial sensing unit will be installed on the bird for the upcoming experiments. The pilot study in February showed promising results. The project is funded by the Navy, and is a collaborative effort between several institutions including Harvard, MIT, NYU, CMU, and WUR. Huai-Ti is also working with MIT engineers to translate the bird observations into strategies that can be used in UAVs maneuvering.

In this over-arching research context, Huai-Ti is specifically interested in some of birds' flight reflexes. Despite the differences in flight mechanics, birds have many wing and tail reflexes analogous to the way aircrafts stabilize themselves. Huai-Ti says that "these context-dependent reflexes are probably mediated by a combination of feed-forward and feed-back control. [Huai-Ti et al] are attempting to quantitatively characterize these reflexes." Furthermore, birds also use their neck to compensate for the movement of the body in order to keep their heads still in flight. This reflex ensures the bird stable vision at all time, critical for visual feed-back. Future UAVs may be able to incorporate more aggressive self-stabilizing camera stages for better imaging.

This collaborative project began just a few months ago as Huai-Ti defended his Ph.D thesis on biomechanics of soft-bodied animal locomotion. When asked about this rapid transition in research subjects, Huai-Ti expressed that "the field of biomechanics is driven by the biological questions and not limited by the animal systems." His primary research interest is motor coordination and locomotor performances; therefore the avian flight maneuver project really captured his attention. Besides, who doesn't wonder how birds fly? *Story by Julia Hisey, a freshman majoring in Biology, and Huai-ti Lin.*

In Flight

In His Words...

Huai-ti Lin Answers Questions Regarding The Research Project

Why biomimetic research? "Nature never charges royalties, but it provides neither technical specifications nor user's manuals, not to mention any warranty. "

Why animal flight? "There is a boy in every man, and there is a flying dream in every boy! I just need to know how come some animals are granted the very dream of mine."

In reference to the most importznt attitude for experimental sciences, like biology...."Never give up, and never give in!"

How to survive an interdisciplinary research setting: "The first step to interdisciplinary work is to disclaim all your titles of expertise."

A bird sports the custom designed head-mounted camera to extract visual information during flight.

A bird is let loose in an arena with artificial obstacles. Photos courtesy of Huai-ti Lin.

Magic and the Brain

Scientists Explore How Illusions Fool the Mind

Imagine it's your final exam. You take a deep breath, pick up your #2 pencil, and focus all your attention on the material you've been learning for the past semester. The multiple-choice questions seem straightforward so you finish, turn in your scantron sheet and leave the exam feeling accomplished. You then begin looking over your exam questions and answers. You notice that you answered the first question incorrectly: "All of the following are true about cognitive illusions except…" Why did you choose A? A was the most obviously true statement: cognitive illusions reveal gaps in the attention system of the brain. Although it may seem as though the word "except" only appeared after you turned in your exam, it really was there all along. It feels like someone had waved a magic wand and made the word appear after you turned in the exam.

Though your professor is probably not a wizard, your speculation of magic playing in a role in this situation is not necessarily outlandish. After all, magicians use this technique all the time. This phenomenon that magicians are trained to manipulate is called inattentional blindness. Your attention was so focused on recalling material from your study guide while reading the question, that your brain did not even process the word "except." So how else do our brains deceive us? And what does "magic" say about our capacity for attention and perception?

Susana Martinez-Conde and Stephen L. Macknik have dedicated their careers to exploring these aspects of neuroscience in the context of magic. In their book, Sleights of Mind, they outline what happens on a cognitive level when magic tricks are performed, and what these incidents reveal about attention and perception in the brain [1].

The attention system of the brain is a highly complex network, involving many parts including the left and right hemispheres [2]. Although it interacts with many a variety of cognitive systems, the attention system is unique in its role in orienting sensory events, detecting signals for focal processing and maintaining consciousness and alertness [3]. Blood flow studies and stimulation tests have identified which parts of the brain are involved in these three categories of the attention system. In this system, a stimulus begins in the brainstem, at the arousal center then travels through the limbic system and then to the cortex, connecting to the parietal and frontal cortex [4]. When analyzing the neuronal basis of magical tricks, visual signals and alertness play a key role in how attention can be manipulated by magicians.

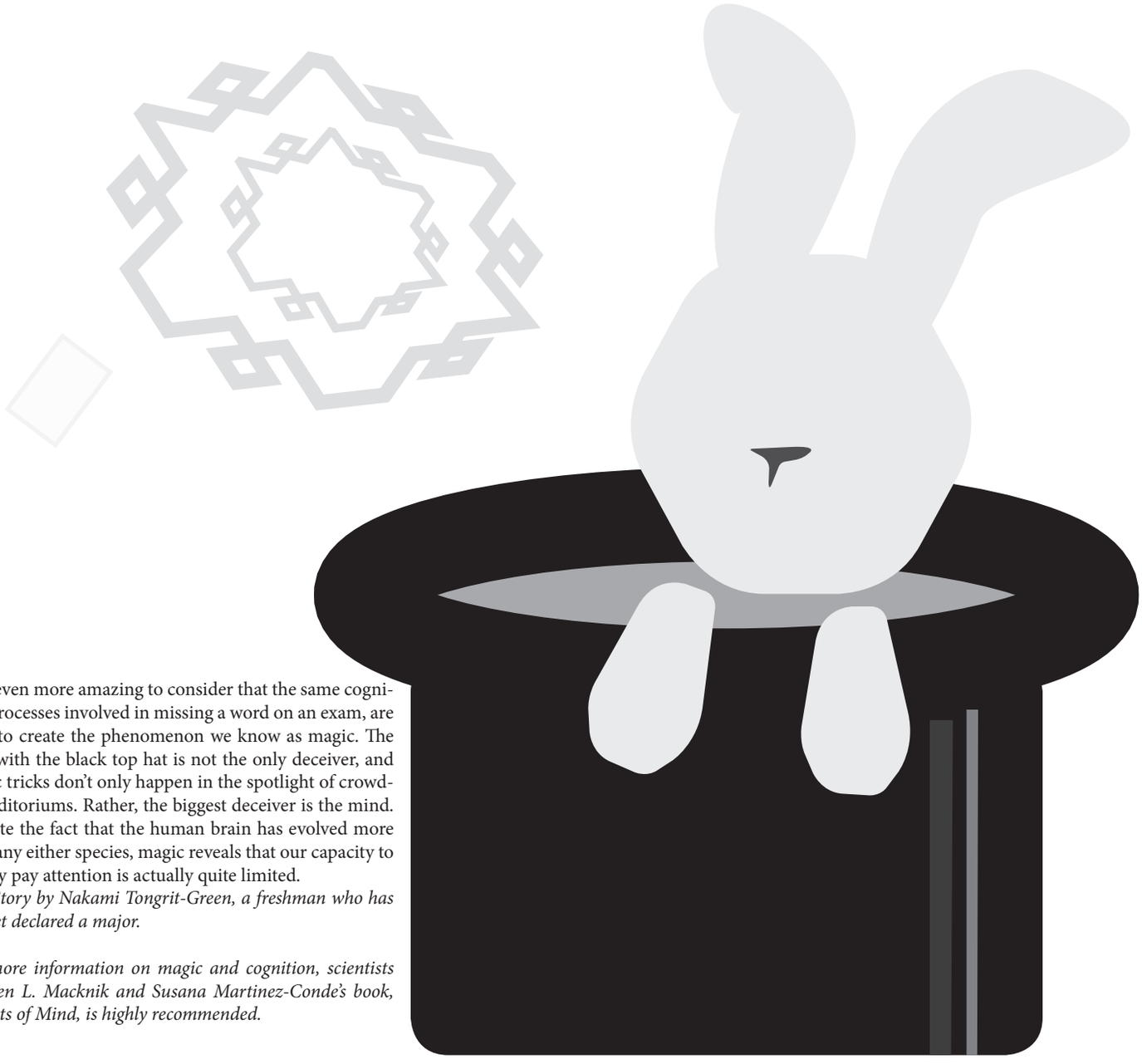
Perception is the way in which our brain processes sensory functions such as taste, sound, smell and sight. Perception, like the attention system, also involves several areas of the brain and incorporates a variety of cognitive functions. Perception involves the somatosensory system, which outlines the paths of sensory pathways in the brain. Perception changes throughout the development of the brain, as senses develop and intellectual capacities increase [3].

In their informal research of magic and neuroscience, Stephen L. Macknik and Susana Martinez-Conde identify 3 types of illusions magicians use to manipulate attention and perception: visual illusions, cognitive illusions and optical illusions. Visual illusions produce subjective perceptions of a situation by manipulating eyesight; cognitive illusions manipulate higher-level cognitive functions such as attention and perception, and optical illusions do not result from any brain process [4]. Magicians use their expertise to produce one of these illusions in the spectator's mind.

Spoon bending is one of the oldest magic tricks. The magician shakes a spoon horizontally which gives the spoon a flexible appearance, while claiming to bend the spoon with his mind. What is happening on a cognitive level involves end-stop neurons, which respond to motion and termination of a stimulus' edges. There is a spatial dislocation between the center of the stimulus and the terminal ends of the stimulus, which gives the spoon a flexible appearance [4]. The magician manipulates the viewer's perception to create the visual illusion of bending.

Cognitive illusions are more complex, and require more expertise by magicians, than visual illusions. Attention is often the system manipulated in cognitive illusions and this diversion of attention is referred to as "misdirection." Magicians use misdirection to perform secret acts while the audience's attention is focused on something else. This technique can be applied overtly or covertly. Covert misdirection, considered the most elegant form of magic, includes change-blindness and inattentional blindness. Change blindness involves a failure to notice a difference due to changes in a visual scene, while inattentional blindness is failure to notice an unexpected object in plain sight [4]. One example of inattentional blindness is the famous vanishing ball illusion. The magician throws a ball in the air several times so that the audience gets used to seeing this image. Then, the magician acts as if he is going to throw the ball in the air again, but instead holds it. Because the audience is expecting the ball to be in the air, it gives the illusion that the ball has actually disappeared, although it is in plain sight.

It is hard to believe that the human brain actually falls for these tricks.



And even more amazing to consider that the same cognitive processes involved in missing a word on an exam, are used to create the phenomenon we know as magic. The man with the black top hat is not the only deceiver, and magic tricks don't only happen in the spotlight of crowded auditoriums. Rather, the biggest deceiver is the mind. Despite the fact that the human brain has evolved more than any either species, magic reveals that our capacity to simply pay attention is actually quite limited.

Story by Nakami Tongrit-Green, a freshman who has not yet declared a major.

For more information on magic and cognition, scientists Stephen L. Macknik and Susana Martinez-Conde's book, Sleights of Mind, is highly recommended.

Super Cool, Dude!

A new method for cooling gases could find applications in research, medicine, and nanoscale manufacturing.

Mark G. Raizen of the University of Texas at Austin has developed a pair of methods to help cool, or decrease the kinetic energy of, almost any gas. The first method employs a reverse atomic coilgun, which consists of a series of helixes. As a current runs through each helix, a magnetic field is generated in the center of the coil in the opposite direction of the atom beam, which decelerates the atoms as they travel through the chamber. The thin stream of atoms slows to leave a chamber of gas at the end of the stream somewhere around 0.01 degrees Kelvin. Zero Kelvin, or absolute zero, is where all motion ceases and no further removal of heat is possible.

The second technique, called single-photon cooling, uses a pair of laser beams to create a one-way barrier, confining the gas to a fraction of its previous volume. Atoms are let through at the barrier one at a time, and retain their initial velocity. This confinement is different from applying pressure to the gas, which would similarly decrease the volume but would increase the atoms' temperature. The laser beams are then shut off, allowing the atoms to spread to their initial volume and cool. As they expand, the atoms do work on their environment, thus losing kinetic energy and decreasing in temperature. By allowing for an unlimited release of heat from a sample, this technique seems to violate the continued increase in the entropy, or disorder, of the universe, which is an important principle of physics. In fact, photons from the one-way barrier become scattered during the cooling, preserving disorder and confirming a longstanding conjecture about a similar situation. Using this technique, Raizen and his colleagues were able to cool atoms to 15 millionths of a Kelvin!

Raizen hopes this work will allow researchers to super-cool hydrogen and antihydrogen in order to study basic properties of chemistry and particle physics that so far have remained inaccessible. The technology could also be used to isolate elements used in medical imaging, and it could advance nanomanufacturing into a new realm, allowing people to build structures just one nanometer across.

Story by Eric Kernfeld. a freshman majoring in Biology and Mathematics.

Stick Out

AMSA Gives Opportunities to Medical Students and Practicing Physicians

Interested in a Health Profession? Before you take the leap, consider AMSA, the American Medical Student Association. For those of you who have spent countless hours shadowing doctors, doing lab research, or even just watching your weekly Grey's Anatomy premiere, consider this: How much insight do I really have from current med students, or practicing physicians?

Every year, there are two annual AMSA conferences, one in the fall and one in the spring. Members of the Pre-Med Society here at Tufts organize weekend trips to these conferences, encouraging students to take more action in the "real world" of medicine. Attending such a conference may seem like a tedious, time-consuming event, but has benefits far beyond a simple lecture or presentation. Every year, the conference hosts many members, reaching beyond the scope of simply having physicians by incorporating community health activists and representatives from nonprofit organizations to also speak about their experiences. Top officers and leaders from some of the countries' finest institutions are available to offer advice and guidance, as well as broadcast the latest news in the medical field.

Opportunities are hard to find in the medical world, but at these events, professionals are waiting to serve those who are interested. It is likely to meet doctors who are looking for potential research fellows, or develop contacts for a prospective career in medicine. For those on the fence, many health and science topics are discussed, such as how to go beyond the realms of medicine and into the greater realm of public and international health in general.

From the standpoint of a prospective pre-med student, it is easy to become drowned by the requirements of being a pre-med student with only the concept of "doctor" in the back of your mind. Sometimes, it is essential to travel out of the comfort zone, and travel to a place that may give you a better grip on the advantages and disadvantages of the medical profession. If you are interested in AMSA, discussion of current health topics, or attending the conferences, weekly dinner meetings have been proposed for Wednesday evenings.

Story by Sonya Bakshi, a freshman majoring in

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