Fall Issue 2011

Volume III

BREAKTHROUGH

Tufts' Undergraduate Science Magazine

HOW MOTHS ARE MORE THAN PESTS

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OTHER STORIES FOUND INSIDE

FROM THE EDITOR

Dear Readers,

Here at Tufts, we are surrounded by an incredible series of breakthroughs all with the potential to help solve some of the world's most challenging issues. These are challenges that require the efforts and insight of people from a variety of fields and skill sets.

As you may learn from this issue's faculty profile on Professor Kurt Pennell, who values the combination of science and engineering, these challenges, such as a large-scale oil cleanup in Kuwait, are complicated not only by scientific factors but also by the surrounding political climate. This semester's magazine also features the on-campus efforts of Professor Grant Garven, who is working with Tufts Facilities to help make Tufts more sustainable by combining geologic research with campus energy needs. A little further from home, the work of Professor Samuel Kounaves and his team combined wet chemical analysis with space exploration to develop our understanding of not only the geochemistry of Mars but also that of Earth.

Considering the rapid developments of science and technology, it will become increasingly important to be able to communicate our ideas effectively and efficiently – a task that will require the efforts of many. This kind of interdisciplinary focus is something we are all exposed to at Tufts. For example, every freshman, including students in the School of Engineering, must fulfill an English requirement. Through foreign language requirements, students in the School of Arts and Sciences are encouraged to expand their communication skills. The university setting offers us the opportunity to learn how to express ourselves through various forms –from works of art to mathematical proofs.

This semester, a professor referenced C.P. Snow's 1959 lecture "The Two Cultures" and Snow's argument about a divide between the cultures of science and humanities. It seems that this gap is closing a little more each day. The proof is in what we learn- from interdisciplinary literacy to science and technology (like the Science, Technology, Engineering, and Mathematics Education Coalition). The proof can also be seen in the growth of this magazine thanks to a well-rounded, passionate staff with diverse interests and talents. We hope that our magazine will do its part in bringing science a little closer to us all.

Thanks for reading!

Warmest Regards,

Catherine Hoar
Editor-in-Chief

Cover image by Noah Paulson
Additional illustrations by Lucia Smith and Megan Berkowitz

OUR STAFF

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tuftsresearch@gmail.com

BREAKTHROUGH

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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., Eaton 207) or e-mail us at tuftsresearch@gmail.com.

WORLD SCI

OCEANS – SIXTH SENSE

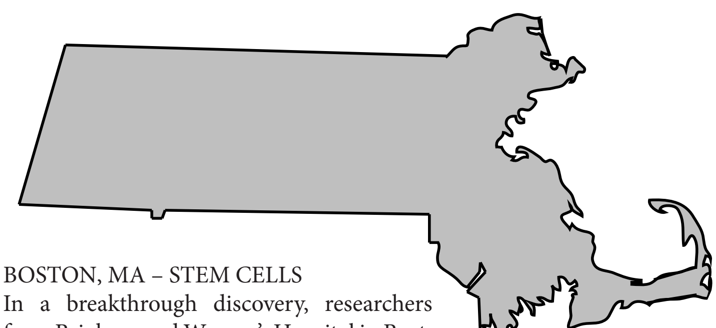
The sixth sense is no longer just a term that appears in creative novels or super-hero movies, but rather a function that may have been possessed by a shared ancestor of a majority of vertebrates, including about 30,000 species of land animals and similar number of ray-finned fish. This sixth sense is a well-developed electro-receptive system.

A 25-year-long study, which was published in *Nature Communications* on Oct.11, shows that this ancestor of roughly 65,000 living vertebrate species that lived approximately 500 million year ago was probably a predatory marine fish with an electro-sensory system.

Most modern decendents of this fish no longer possess the "sixth sense;" however, some land vertebrates do. One example is the Mexican axolotl, a kind of salamander, which is the model organism for researchers studying the development of this electroreception system. Some ray-finned fish, like the North American paddlefish, also have electrosensory systems.

Researchers have analyzed the evolution of the linages leading to both land animals and ray-finned fish by studying the Mexican axolotl and North American paddlefish. They discovered that those electroreceptors develop accurately just like the embryonic tissue of the developing skin. This confirms that those electro-sensors are modern examples of the ancient system.

By Keran Chen



BOSTON, MA – STEM CELLS

In a breakthrough discovery, researchers from Brigham and Women's Hospital in Boston have announced that they have potentially found the first recorded case of human lung stem cells.

The findings, published in the New England Journal of Medicine, have generated debate surrounding the current understanding of the development of the human lung, and its ability to recover from damage. Using lung tissue samples from previous surgeries, a research team was able to hunt for specific cell markers to isolate and identify potential lung stem cells. The researchers determined that the cells were able to proliferate in culture ('in vivo') mice lungs, and differentiate into specialized lung tissues, such as those that make up the alveoli and bronchioles. These cells were then inserted into injured lungs of mice. The cells were not only able to form healthy pulmonary vessel cells, but also assimilated into the pre-existing tissue, thus fulfilling the three qualifications of stem cells: self-renewal, clonogenicity (the ability to form clone cells), and multipotency (the ability to give rise to multiple types of cells from the same lineage).

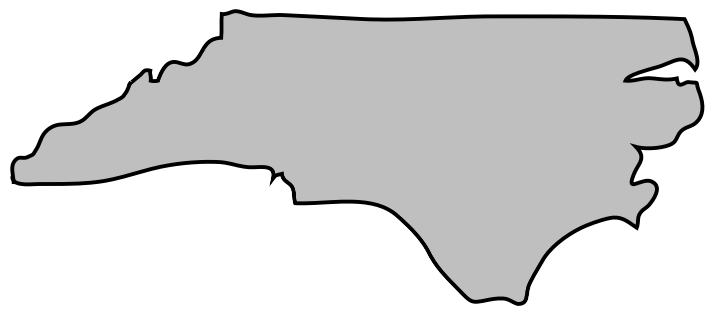
Although the findings have yet to be confirmed in reproduced trials, the results have prompted renewed interest into the possibility of the existence of human lung stem cells, and with it the possibility of potential treatments for lung damage and diseases such as emphysema.

By Annirudh Balachandran

WINSTON-SALEM – NC 3-D Printing

As the necessity for functional organs nearly doubles for patients, the number of organs available for transplants has hardly changed at all. With this trend continuing, scientists desperately research newer and more effective forms of regenerative medicine, the latest of which is what is referred to as '3D printing.' This new technology scans organs layer by layer, and then transfers the information to a computer. The computer maps the layers into a 3-Dimensional figure and "prints" the object with special thermo-reversible gels to form a skeleton-like organ. Surgeon Anthony Atala at the Wake Forest Institute for Regenerative Medicine printed a human kidney in front of a live audience, proving the promising future that lies ahead for this new technology. Although these prototype organs are years away from functional, clinical use, it provides the possibility for a viable and feasible solution in the near future for kidney failure, diabetes, and many other diseases.

By Santosh Swaminathan



BOULDER, CO – SNAKE HEART

You may want to change your mind if you're deathly afraid of snakes – they might just save your life. A University of Colorado research team's examination of post-meal changes in Burmese Pythons' heart size may lead to the production of new drugs for human heart disease, diabetes, high blood pressure, and obesity.[1]

As pythons digest their prey whole, their hearts and other internal organs rapidly enlarge before shrinking down to normal size around two weeks later.[1] The research team discovered that the snakes achieve this growth not by producing more heart cells but by hypertrophy, a process in which existing cells expand.[2] In humans, cardiovascular hypertrophy can either be a harmful sign of a heart attack or a beneficial growth caused by frequent exercise. The new study shows that python hypertrophy is comparable to the advantageous form of expansion often found in athletes' hearts.[1]

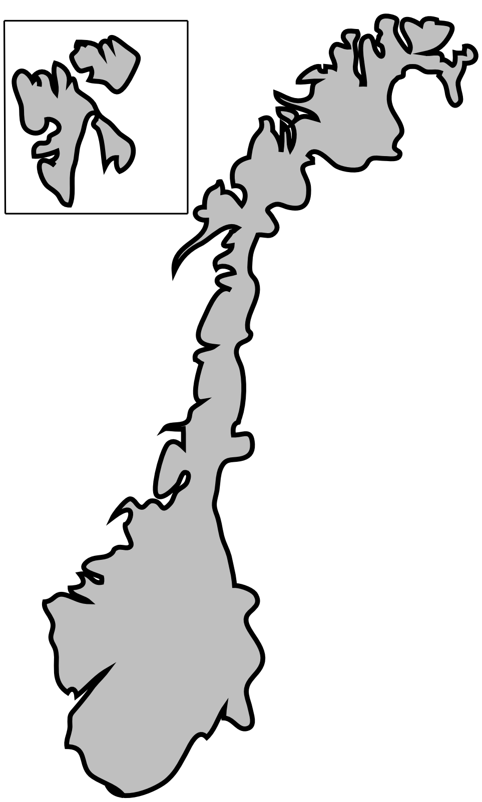
The research team also ascertained that a combination of three fatty acids causes this swelling in python hearts. They were able cross their research over to mammals by injecting mice with this mixture. The mice's hearts experienced the same beneficial hypertrophy as the pythons'.[2]

Though the research still has a long way to go before it can be applied to humans, it could potentially lead to groundbreaking treatments for heart disease.

Someday, people may owe their hearts – and their lives – to the incredible digestion process of pythons.

By Scott Sugarman

ENCE NEWS



NORWAY – REINDEER

With thick coats of fur ideal for keeping the heat in, even reindeer need a way to cool down. In a study published in the November 15th issue of The Journal of Experimental Biology, Arnoldus Blix of the University of Tromso in Norway and colleagues reveal three methods reindeer use to keep their brains cool while exercising.[1] The team gathered their findings by studying the breathing, blood flow, and brain temperature of reindeer as they ran on treadmills.[2] Blix and the team saw that as their brain temperatures rise, reindeer first pant through their noses. They then begin to pant through their mouths. These methods of cooling allow evaporation from the reindeer's noses and mouths in the same way that panting helps dogs keep cool. When the level of heat increases further, the team found that the reindeer undergo selective cooling of the brain through diverted blood flow from the nose to the head.[2]

The experiments required Blix and the team to train the arctic animals to run on treadmills. The reindeer ran at temperatures ranging from 10 to 30°C at a pace of nine kilometers per hour.[2]

By Catherine Hoar

CHINA – AIR

Air pollution is a major problem in China, but it seems that there is an inconsistency in which populations are plagued by pollution and which have the privilege of purified air. Namely, it has been reported that expensive devices for filtering air are found in the homes and offices of China's elite. There has been controversy over whether the Chinese government is making the extent of the pollution unclear deliberately. Environmental officials in China do not release data on particulates of less than 2.5 micrometers to the public and only release information on larger pollutants (above 10 micrometers). According to scientists, the smaller particulates are the most dangerous kind since, in comparison to the larger particles, they can penetrate the lungs more deeply.

The Ministry of Environmental Protection revealed in September 2011 that it would work to include these small particulates by changing China's air quality standards by a yet undetermined point. However, Beijing officials do not agree with adopting these standards. To counter the criticism of the recent large amounts of smog, they proclaimed that the Beijing's air is only "slightly polluted," despite what the embassy monitor said – the air was hazardous enough to exceed measurable levels.

By Karen Chen.

Nobel Prize 2011

Physiology and Medicine: Bruce Beutler (USA) and Jules Hoffmann (France) with Ralph Steinman (Canada)

The activation of Innate Immunity and the discovery of dendritic cells:

Our bodies are able to keep the various pathogens around us at bay thanks to a series of immunological responses. This year's Laureates were honored for their discovery of receptor proteins that activate the body's first response against microorganisms (innate immunity) as well as dendric cells that function in active immunity to rid the body of infectious microbes.

Physics: Saul Perlmutter, Brian Schmidt, and Adam Riess (USA)

The discovery of the accelerating expansion of the universe:

Through the quest to find type la supernovae, a particularly bright and vivid explosion, the researchers discovered that not only is our universe expanding, but it is doing so at an accelerating rate. Their findings predict a very chilling end for the universe, at the hands of the little known, dark energy.

Chemistry: Dan Shechtman (Israel)

The discovery of Quasicrystals:

Atoms are generally thought to form symmetrical crystallized structures in solid matter. However, Shechtman's discovery of quasicrystalline structure, an unrepeatable configuration of atoms, lead to fierce debate over the structure of matter. Currently quasicrystals are being researched to develop a wide range of more effective materials and products for consumer use.

Compiled by Annirudh Balachandran

The Tufts GeoJumbo Array

Professor Grant Garven's research sparks sustainability projects on campus

PHOTO COURTESY OF PROFESSOR GARVEN
The drilling of the geothermal well outside Lane Hall.

Professor Grant Garven, of the Tufts University Geology Department, began drilling wells on campus over three years ago to create an on campus laboratory for his groundwater hydrology students, but starting this year his work is set to become the next step in Tufts' goal to become a more sustainable university.

Professor Garven's collection of wells, known to the Geology Department as the GeoJumbo array, began as three shallow wells dug in the summer of 2009. The project continues today to include 13 wells across campus. Many of these wells are used strictly for academic purposes by Professor Garven and his groundwater students to develop a deeper understanding of how groundwater is flowing beneath campus. However, Professor Garven's on-campus exploration has recently also led to two potential uses of the groundwater below us – geothermal energy and the irrigation of the athletic fields.[1]

During the summer of 2010 Professor Garven dug a deep (700ft) well just outside of Lane hall to investigate the geothermal heating potential of the bedrock below Tufts. After a series of tests, Professor Garven has determined that this well could be used as a geothermal energy source, and, in conjunction with Tufts facilities, a test program for on-campus geothermal heating will be installed in Lane Hall as early as this winter. Once connected, this geothermal well will heat and cool one classroom in Lane Hall using only the energy from the earth below us.

> "Professor Garven has determined that this well could be used as a geothermal energy source…on-campus geothermal heating will be installed in Lane Hall as early as this winter."

Geothermal heating and energy production operates on the basic premise that Earth's shallow subsurface maintains a relatively constant temperature of between 50° and 60°F.[2] In order to benefit from this heat radiating from the Earth's core, a closed loop of pipes is created going from the subsurface to the building that is to be heated and back. Water is then continuously cycled in this loop. Due to the constant nature of subsurface temperature, geothermal heating systems have heating and cooling capacities. In the winter heat from the ground will be release heat into the building, and in the summer heat from the air will be captured and released into the bedrock.

When asked about the geothermal well drilled by Professor Garven Tufts University Facilities director Bob Burns emphasized that "sustainability is a primary goal"[3] of the facilities department. He thinks the geothermal well is a good learning opportunity for facilities that will also help determine if geothermal energy is something Tufts will choose to pursue in the future.

Many universities and organizations choose not to pursue geothermal energy due to the very high cost of instillation; for larger projects, installation costs are on the scale of tens to hundreds of millions of dollars. Another concern is the amount of energy that can be sustainably utilized from the subsurface; some regions are more conducive to geothermal heating, and determining how much heating capacity a specific location has can only be discovered through testing such as that which facilities and Professor Garven are about to begin. Testing this project will give facilities a clearer picture of the feasibility of a larger geothermal project on campus.

On September 15th of this year, Professor Garven drilled a well adjacent to the Alumni Fields on behalf of Tufts facilities who will be using this well to irrigate the athletic fields. Facilities formally operated another well near alumni fields but after many years of maintenance and breakdowns they were excited to work with Professor Garven on drilling a new well.

PHOTO COURTESY OF PROFESSOR GARVEN
Professor Garven and a student monitor the water table level in a well on campus.

> "Pumping at rates upwards of 60 gallons per minute would allow facilities to irrigate the athletic fields exclusively with water found naturally underneath Tufts."

Irrigating all of Tufts' athletic fields comes at a large cost to the university, making the option to water the athletics fields at almost no cost and in a sustainable manner very appealing to both facilities and the university. While using groundwater to irrigate our athletics fields will save the university money, the reduction in environmental impact due to well water irrigation will be significant.

With this well in place, water will be pumped from the subsurface and immediately used to water the fields above. Water will then infiltrate the soil and return to the well pump where the cycle will restart. By creating a closed system that water will travel in, Tufts will reduce its usage of public water resources, which come with large amounts of energy usage in the transportation, sanitation, and storage of water.

Due to fractures, or cracks, in the bedrock that the Alumni Fields well passes through, water can be pumped at very high rates with almost no impact to the surrounding groundwater systems. Testing by Professor Garven has shown that his new well can be sustainably pumped at 60 gallons per minute, which would fill one of Tufts' many brown barrels in just 55 seconds. Pumping at rates upwards of 60 gallons per minute would allow facilities to irrigate the athletic fields exclusively with water found naturally underneath Tufts.

Over the past three years of academic research by Professor Garven the Geology Department and the university have learned much more about the earth beneath Tufts. As the university continues to become more environmentally conscious, this research is opening possibilities toward sustainable solutions utilizing the water located just a few feet below the surface. As work continues in the fields of geothermal energy and groundwater usage on campus, the university and environment only stand to benefit. *Story by Alex Grant, a junior majoring in Civil Engineering.*

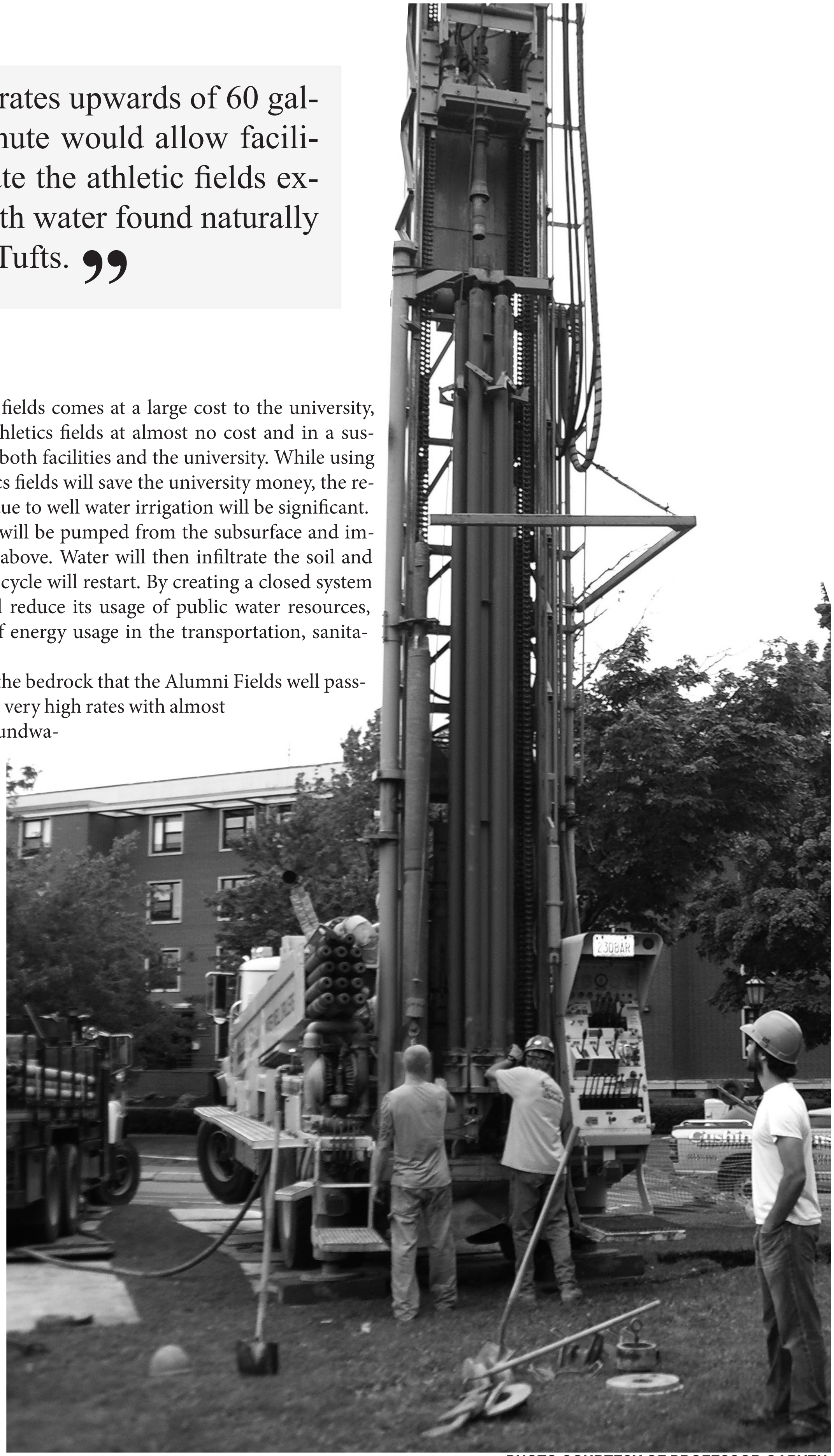


PHOTO COURTESY OF PROFESSOR GARVEN

The drilling of a well on campus.

Sexual selection:

Research conducted through the Lewis Lab in the Biology department at Tufts over the summers of 2010 and 2011 is beginning to shed new light on the effect of nutrition on sexual selection in herbivores.

"We investigated the impact of nitrogen concentration on various fitness-related traits in the cabbage butterfly," Natasha Tigreros, who is in her fifth year as a Biology Ph.D. student at Tufts and conducted the experiments, wrote in an information sheet about her research.

Using the idea of the "herbivore's dilemma" of nitrogen allocation, Tigreros hypothesized that when exposed to varying levels nitrogen, a key nutrient, individuals would "[maintain] allocation to those traits that contribute most to their overall fitness while sacrificing allocation to other traits."

> "The thing that's really exciting about Natasha's work is that it is giving us insight into the interaction between what you eat and how successful you are at reproducing."
>
> – Dr. Sara Lewis

The herbivore's dilemma is the concept that herbivores, whose diets are necessarily low in nitrogen because of the low nitrogen content in plants, must choose carefully how they will use the nitrogen they do consume. In male cabbage butterflies, wing coloration and quality of nuptial gifts are among the males' reproductive fitness-related traits, or traits that affect their reproductive capabilities, in addition to consuming a large amount of nitrogen. Tigreros and her team investigated the impact of low nitrogen concentration in larval diets on these and other fitness- and nitrogen-related traits.

The original experiment, conducted in the summer of 2010, studied butterflies reared on eight semi-synthetic larval diets, each with a different amount of nitrogen. The butterflies' mating behavior was then observed in a large outdoor cage approximating the natural concentration of butterflies.

"Some traits of male reproductive fitness were affected by the concentration of nitrogen in the larval diet," Tigreros said. "We were able to find that wing coloration, which is a trait that is important for male courtship, was affected by diet. Males that were fed with low-nitrogen diets were less colorful than those that were affected with a better-quality diet."

In addition, males that were given low-nitrogen larval diets didn't mate as often as did those with higher concentrations of nitrogen in their diets.

Not all of the traits affecting sexual selection in the cabbage butterflies varied with changes in nitrogen concentrations of larval diets.

"Surprisingly, we didn't find any effect of concentration of nitrogen in the diet on the nuptial gift that males transfer to females," Tigreros said.

These nuptial gifts are nutrient-rich packages transferred to females along with the males' sperm. Females use the nutrients to provision their eggs, according to Dr. Sara Lewis, Tufts professor and evolutionary ecologist in whose lab Tigreros works.

The quality of a male's nuptial gift has an effect on his post-mating paternity success, or the likelihood that the genetic material that he has transferred to the female will actually result in offspring.

"We saw how males are able to … buffer the effects of nitrogen in their diet into keeping some of the important reproductive traits such as nuptial gifts equal while sacrificing other traits like coloration and mate acquisition," Tigreros said.

From this, Tigreros observed that, "keeping the quality of the nuptial gifts even though they are constrained in their nitrogen concentrations is more important for males than investing in traits that [serve to] increase the number of matings."

"The interaction between sexual selection and nutritional ecology is something that people are just beginning to look at," Dr. Lewis said. "The thing that's really exciting about Natasha's work is that it is giving us insight into the interaction between what you eat and how successful you are at reproducing."

Dr. Lewis explained that the manner in which the experiment was conducted contributed to its success.

"By manipulating the diet in a very controlled way…Natasha's been able to really put together a picture of the interaction between what these individuals are feeding on and what kinds of reproductive traits they're allocating their resources to."

What sets her research apart from other research is that she studies the quality and specific makeup of diets, Tigreros said, rather than simply the quantity. As a result, the researchers in the Lewis Lab have been able to test how specific nutrients affect fitness.

The research in the summer of 2011was intended to build on the original experiment, using phosphorous instead of nitrogen as the variable nutrient. In addition, the team's focus shifted from male sexually selective traits to female ones.

"This summer we focused more on the female side of the story," Tigreros said.

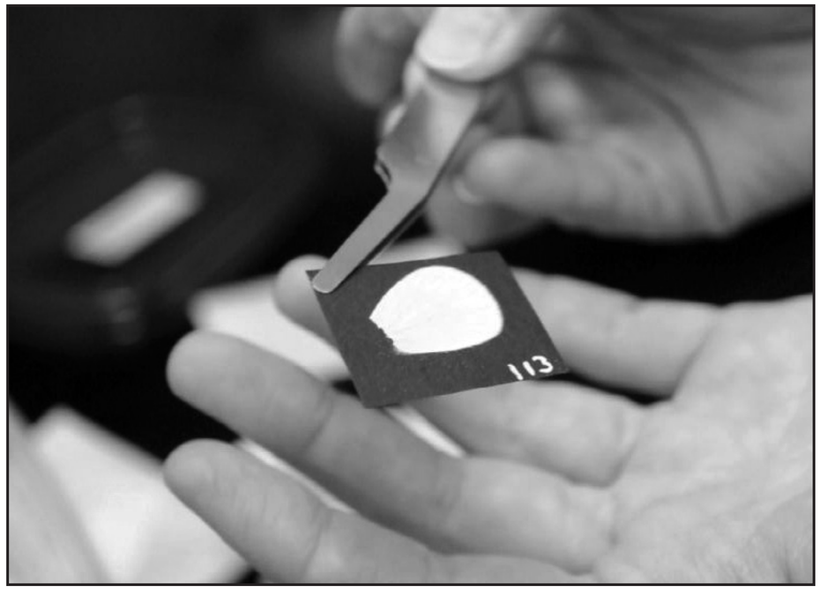
"Females are supposedly 'the choosy ones,'" when talking about evolution and sexual selection, she added. However, she has hypothesized that when males offer nuptial gifts in return for mating privileges, they choose more fecund, or fertile, females to mate with.

The research done already has shown that male butterflies tend to mate with larger females and that fecund females tend to be more colorful, Tigreros said.

She and Monica Mowery, an undergraduate student involved in the research this summer, are in the process of designing and

Lewis Lab investigates link between nutrition, mating success in herbivores

VIDEO STILLS BY MEGAN BERKOWITZ



performing experiments to test males' reactions to both of these traits. They are trying to isolate size from coloration to determine whether one or both of these traits affects males' mate choices.

These experiments tie into the summer 2010 experiments in that diet affects both size and coloration of butterflies, and so the current research is a continued look into how diet affects sexually selective traits in both male and female cabbage butterflies.

Due to a number of small problems encountered over the course of the summer, the research team was not able to perform the experiments on the scale they originally intended, and the large cage setup on the academic quad was not used this year.

"We got some data on how phosphorous affects larval development," Tigreros said, as they did with nitrogen the previous summer.

However, problems that she believes stem from inbreeding and poor diet quality led to a decreased number of eggs hatching and a decreased survival rate of those that did hatch. As a result, they were not able to collect data on adult traits as they had the previous summer.

Tigreros and Mowery are working to correct these issues as they move forward with their research on female fecundity and male mate choice this semester.

"[In scientific research] you plan things, but it's going to change," Tigreros said. "There's a lot of improvisation."

Story by Megan Berkowitz, a sophomore who plans on majoring in Englisn and Biology.

VIDEO STILL COURTESY OF DR. SARA LEWIS

CLOCKWISE FROM TOP:

Biology graduate student Natasha Tigreros examines butterfly wings collected during the summer of 2010.

Tigreros displays one of the wings, which has been mounted and saved to gather data about the coloration of males' wings in relation to their diets. It was found that the amount of nitrogen in diets significantly affects wing coloration in male cabbage butterflies.

The cage pictured, which was set up on the Academic Quad for a portion of the summer of 2010, was created by Tigreros and her team to house butterflies for some experiments.

A Science Sit-down with President Monaco

This October, Breakthrough sat down with President Anthony Monaco to learn more about his scientific background, as well as his life and interests here at Tufts.

President Monaco first became interested in a career in science while taking AP Biology in high school. His godfather was a neuropathologist at Rutgers Medical School, where President Monaco was able to work and gain research experience. His passion for neuroscience led him to create and pursue his own Independent Concentration (Major) in Neuroscience and Behavior during his undergraduate years at Princeton University. He continued to spend his summers conducting research at Princeton, where he published his work in scientific journals. This experience in the lab helped him realize his desire to attend medical school and further broaden his understanding of biomedical research. Although he did not foresee a career in clinical medicine, he chose to complete a combined MD/PhD program at Harvard Medical School to compliment his research in the biomedical field.

Later, President Monaco received an offer to work on the Human Genome Project in London. He set up his own lab in Oxford, where he helped found The Wellcome Trust Centre for Human Genetics--a multidisciplinary genetic research center whichfostered collaborations between experts in biology, neurology, pediatrics, and other clinical departments.

During his career, Monaco became interested in neurodevelopmental disorders--focusing heavily on autism--and strived to learn more about genetic susceptibilities and interactions. However, in reflecting on all of his past research, Monaco admitted that his favorite aspect of the whole process was being able to mentor students with their careers.

After many years of research at his lab in Oxford, he was appointed Pro-Vice-Chancellor of Planning and Resources. This new administrative role (one which saw him working with members of academia throughout the university) launched him into a world very different from that of medicine. Although he continued to work with his lab, Monaco said he liked the fresh perspective of a leadership position. The transition to Tufts offered him a similar opportunity, but in this case the move was a bit more difficult. Monaco explained, "I will miss many aspects of my life in Oxford, including many friends and colleagues from over 20 years there, but I look forward to meeting new colleagues in the Tufts community."

Monaco recognizes that Tufts has a great academic foundation and explained that by working together with faculty, it can be even further strengthened when considering the challenges and strongpoints of a university. Regarding Tufts academics, President Monaco respects the science departments as well as the arts and the humanities, yet he admits that his own science background has greatly influenced how he thinks and looks upon the events around him. Monaco combines this science perspective with a deep appreciation for diverse points of view. He explained that any individual alone can create a hypothesis, but only by interacting with groups of people and rethinking (or carrying out experiments), can this hypothesis come closer to the truth. He says goals are accomplished "by consensus… rather than coming from one individual."

President Monaco is eager to become integrated into the Tufts community, and urged us all to respect different views of our peers around us. He left us with this comment: "Everyone comes with their own perspective on an issue." Speaking out and voicing our opinions, actively trying to instigate change – these are the qualities that truly set Tufts apart. *Story by Sonya Bakshi and Julia Hisey, sophomores majoring in Biopsychology and Biology, respectively.*

Glowing in the dark

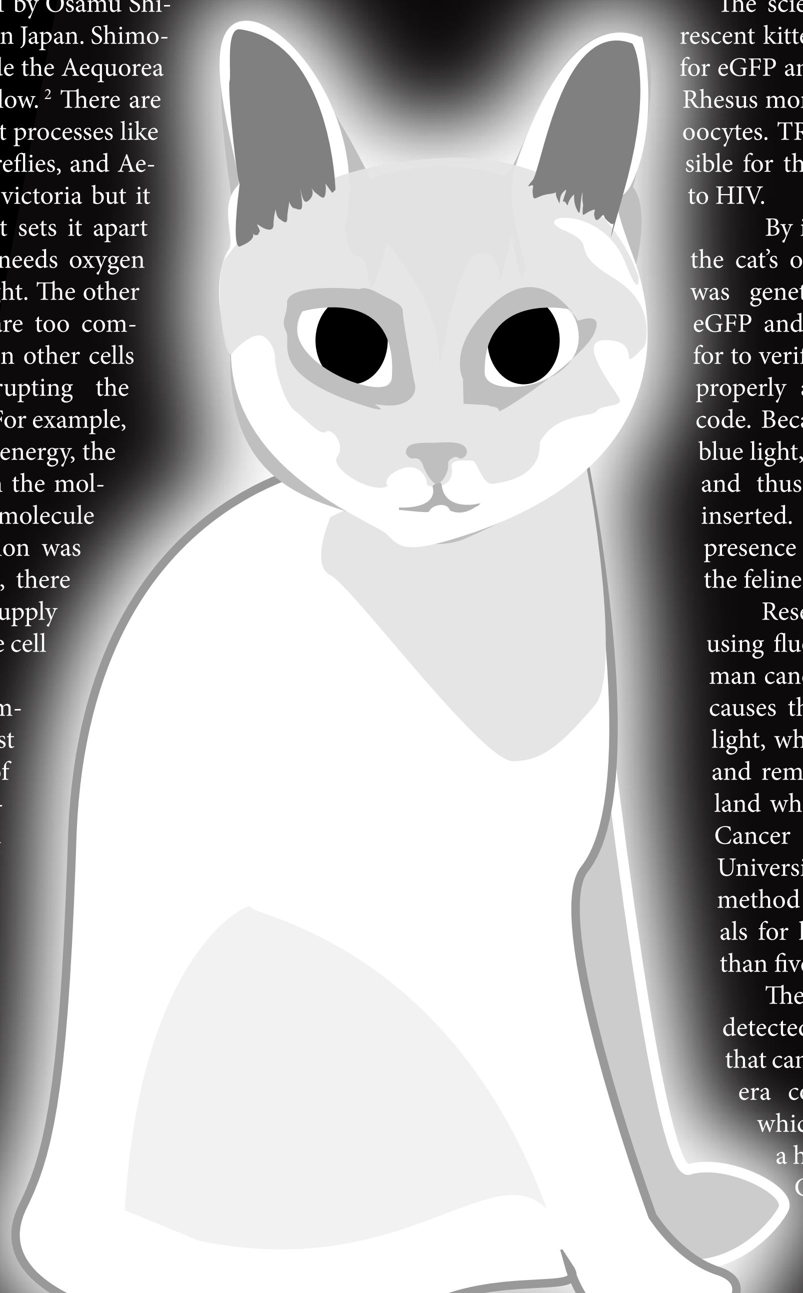
The science of how kittens can help HIV research

In October 2011, scientists from Mayo Clinic proved they could make kittens even cuter. The scientists created genetically modified kittens that produce enhanced green florescent protein (eGFP), which causes them to glow under blue or ultraviolet (UV) light.[1]

GFP was isolated in 1961 by Osamu Shimomura, a graduate student in Japan. Shimomura was studying what made the Aequorea victoria, a type of jellyfish, glow. [2] There are other types of bioluminescent processes like Luciferin-Luciferase, from fireflies, and Aequorin, also from Aequorea victoria but it is the simplicity of GFP that sets it apart from the others. GFP only needs oxygen to glow under UV or blue light. The other bioluminescence processes are too complex to artificially duplicate in other cells consistently without interrupting the natural processes of the cell. For example, in fireflies, if there is enough energy, the protein luciferase reacts with the molecule luciferin, causing the molecule to oxidize. So if this reaction was transplanted into a new cell, there would have to be a constant supply of energy and luciferin for the cell to continuously glow.[3]

Martin Chalfie (Columbia University) was the first to explore the possibilities of inserting GFP into other animals. He thought of the idea when he was at a seminar in 1988 about bioluminescence given by Paul Brehm, a neurobiologist at Tufts University Medical School. In the early 1990's Chalfie successfully inserted GFP into Caenorhabditis elegans, a millimeter long transparent roundworm, and mapped the nervous system of the worm.[4]

In the mid-1990's, Roger Tsien experimented with rearranging the amino acid sequence of GFP. This resulted in new fluorescent proteins that glowed different colors with greater intensity, including eGFP. GFP and its derivatives are now used to track proteins, gene activity, cells, and even individual components of cells.[2]



The scientists working with the fluorescent kittens inserted genes which code for eGFP and TRIMCyp, a protein from a Rhesus monkey, into an adult female cat's oocytes. TRIMCyp is the protein responsible for the Rhesus monkey's immunity to HIV.

By inserting the genetic code into the cat's oocytes, or eggs, her offspring was genetically modified to produce eGFP and TRIMCyp. eGFP was coded for to verify that the TRIMCyp gene was properly added to the kitten's genetic code. Because the kittens glowed under blue light, the scientists knew that eGFP, and thus TRIMCyp, was successfully inserted. The scientists proved that the presence of TRIMCyp helps cats resist the feline immunodeficiency virus.[1]

Research has also been conducted using fluorescent proteins to track human cancer cells inserted in mice. This causes the tumors to glow under UV light, which makes them easier to find and remove.[5] Professor Norman Maitland who is the head of the Yorkshire Cancer Research Laboratory at the University of York estimates that this method will be available in clinical trials for human cancer patients in less than five years.

The glowing cancer cells are then detected using a specialized camera that can look into the body. Each camera costs approximately $800,000, which is why this method is only in a handful of laboratories.[6] Even if GFP is not used in clinical trials in five years, it still has a bright future in helping animals.

Story by Amelia Downs, a sophomore majoring in Physics and minoring in Math.

ILLUSTRATION BY CHINAMI MICHAELS

World's Smallest Electric Motor

Researchers in Dr. Sykes' lab create a motor made of a single molecule

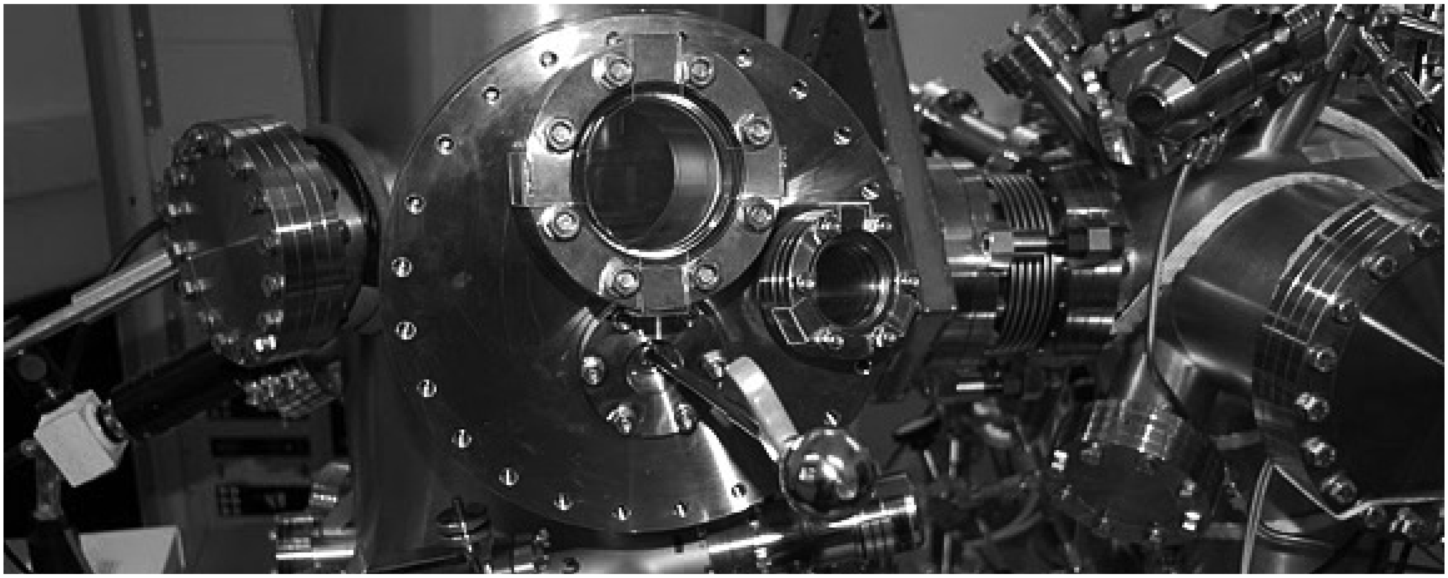


PHOTO BY NOAH PAULSON

Some of the machinery used by Dr. Sykes' research group.

When most people think of a motor, the image that comes to mind is a large, bulky machine with many complicated mechanical parts. Researchers in the lab of Dr. Charles Sykes, an Associate Professor of Chemistry at Tufts, have successfully created an electric motor that shatters this stereotype. Recently confirmed by Guinness World Records as the world's smallest electrical motor, it is made of a single molecule, butyl methyl sulfide, and is approximately one nanometer wide.[1]

According to Sykes, the project began in 2007 with the realization that this butyl methyl sulfide molecule, which could stick strongly to metal surfaces, had the potential to act as a molecular rotor, which is a precursor to being a motor. "To everyone else it just looked like some molecule on the surface but to chemists, we got the sense that it might have the basic backbone structure of a rotor. Not a motor, but a rotor." Although rotors and motors are closely related, they are also very different in terms of function. Both rotors and motors spin, but in order for something to be a motor, that rotation must be directed. "It's easy to make a rotor because you can make something that just rolls around a surface and spins, but it's much harder to get the directed rotation," Sykes explained, which makes his group's achievement even more remarkable.

While this technology is relatively new in the man-made world, the biological world is full of things like muscles, cells and bacteria that utilize and are powered by forms of molecular motors. "Nature is full of molecular motors, but apart from liquid crystals, there's nothing technologically available today that really harnesses nanoscale motion," Sykes stated. The motor that Sykes' group has discovered functions very similarly to the way that these motors in nature are thought to function: its power is used to strategically influence its direction of motion, rather than to continuously move in one direction. In other words, each time the motor is excited by an electron, it relaxes to a slightly tilted state in which it is then more likely to rotate toward one direction than the other. "That's why when we report in paper, '5% directionality,' it doesn't sound that impressive, but it's basically functioning by completely different mechanisms than a regular motor," Sykes explained. "It's jiggling around, but overall, it's making its way around in one direction, so it's much more analogous to a biological system than an electric motor you'd buy in a shop."

This is not a completely new innovation in the world of science, however, as other types of molecular motors have previously been created. The reason that Sykes' motor particularly stands out is that it is electrically powered, which is something that had not been achieved up to this point. The other ways of powering molecular motors, which include chemically-driven and optically-driven methods, address billions of molecules at a time, which is not ideal for extremely precise measurements. "With the electrically-driven

> "The world's smallest electrical motor is made of a single molecule (butyl methyl sulfide) and is approximately one nanometer wide."

[motor] we were excited because we could really address just one molecule at a time and watch what it's doing as it spins in real time, rather than making just an average ensemble measurement," Sykes said.

While Sykes admitted that practical use for the motor is still "fairly distant," he mentioned that one potential application for this technology could be in signal-delay lines for cell phones. This would work by creating a line of charged rotors, one end of which would be hit by the signal. The signal would slow down from light speed (very fast) to a much slower rotational speed as the first rotor started rotating, which would rotate the second rotor, and so on; this would continue down the line until the signal reached the other end. As Sykes put it, "Every step along the way is realizing those nanoscale devices that can interface between optical signals, electronic signals, and even mechanical motion."

Although they achieved their long-term goal of creating a functional single-molecule electric motor, Sykes' research group continues to work on the project. One potential idea is a nanoscale gearbox, in which the rotation of one rotor is directed and this power is then transferred and used to control the rotation of the rotor next to it, and so on. "We're definitely trying out different things right now. We don't want to just make five different versions of a motor and make small changes; we want to try and find another fairly fundamental issue."

Story by Brian Pedro, a sophomore majoring in Chemistry.

PHOTO BY NOAH PAULSON

ABOVE: From left, Emily Lewis, Professor Sykes, Colin Murphy, and April Jewell, members of the Sykes Lab molecular motor team, pose with their Guinness World Records certificate.

INSET AT RIGHT: This Guinness World Records ceritificate was awarded to the Sykes Lab molecular motor team, acknowledging that their motor is the world's smallest in existence.

U.S. Science News

Researchers pinpoint dinosaur body temperatures

Caltech geochemists gather new info from old fossils

The study of dinosaur fossils is hardly a new science, yet we still know relatively little about their physiology. Many scholars disagree on the issue of temperature regulation and metabolism. Until recently, there were few concrete answers regarding whether Tyrannosaurus Rex, Triceratops, and company were capable of regulating their own internal body temperature, let alone what this temperature was.

Caltech geochemistry postdoctorate Robert Eagle and several other researchers may have found a key to the answer. Along with Caltech geochemistry professor John Eiler, the team examined 11 fossilized teeth from several sauropods, including Brachiosaurus. Their approach implemented clumped isotope thermometry, which involves measuring the amount of chemical bonds between the rare carbon-13 and oxygen-18 isotopes in fossils.[1]

The inverse relation between body temperature and the formation of bonds between carbon-13 and oxygen-18 led the team to discover that the group of sauropods had body temperatures from 36 to 38 °C (96.8 to 100.4 °F), closer to those of modern mammals than modern reptiles or birds.[1] Present-day lizards have a thermal preference range from 24 to 35 °C (75.2 to 95 °F),[2] while humans have a normal body temperature of 37 °C (98.6 °F).

However, these results do not necessarily mean that large dinosaurs relied on self-regulating systems similar to those of modern mammals. Speaking with the New York Times, Eagle explained that the sauropods probably had "the capacity to retain environmental heat just as a function of being so large… [and] might have had physical adaptations, like an internal air sac system," to cool them down.[3]

In any case, Eagle's findings could possibly aid other researchers attempting to explain the metabolistic processes of the dinosaurs. The team's discovery of this temperature range will perhaps provide a valuable testing point for the validity of future physiological models.[1] *Story by Scott Sugarman, a junior majoring in English.*

Tufts-in-Chile, Tufts-in-China, Tufts-in-Ghana, Tufts-in-Hong Kong, Tufts-in-Japan, Tufts-in-London, Tufts-in-Madrid, Tufts-in-Oxford, Tufts-in-Paris, Tufts-in-Tubingen and

Tufts-on-Mars:

Tufts technology made its appearance on Mars aboard the Phoenix Lander in the summer of 2008. The Phoenix landed in the Martian arctic (a region similar to central Greenland or Northern Alaska on Earth), where it collected and analyzed samples of ice and soil. The primary goals of the mission were to investigate the geochemistry of Mars and assess its potential biohabitality for past and future life.[4] The Phoenix carried the Wet Chemistry Laboratory (WCL), designed by Professor Samuel Kounaves of the Tufts Chemistry Department and his team. The goal of the WCL was to detect inorganic ions and other properties of the Martian soil, a first in geochemical analysis of another planet. The results of Professor Kounaves' research established surprising connections between Earth and Martian environments and are still providing us with valuable information on Mars' potential to sustain past and future life.

The WCL is essentially "a chemistry lab in a cup," Dr. Kounaves explained. The device is made up of four identical cells, each equipped with a lower beaker containing a number of sensors, a stirrer, and an upper water actuator. The tank contains 25 mL of water with small amounts of the necessary ionic species. These ions are used for the initial calibration of the sensors and are placed in the beaker before the actual Martian soil comes in.[3] Each cell of the WCL contains sixteen Ion Selective Electrodes (ISE). These are sensors that measure the electric potential of a specific ion and are used to determine the concentration of the ion in the solution. The WCL tested for a number of common inorganic anions (negatively charged ions) and cations (positively charged ions), including Ca^{2+}, Mg^{2+}, K^+, Na^+, NH_4^+, Cl^-, Br^-, I^-, NO_3^-, ClO_4^-, and SO_4^{2-}. Other sensors also tested for pH, redox potential, and conductivity.[3]

> "If just one percent of ClO_4 in soil is mixed with organic substances and heated to at least 300 degrees (the temperature at which the soil is analyzed), the ClO_4 oxidizes all of the organic compounds and forms CO_2."

Each day by 9:30 a.m., all the electrodes in the cells of the WCL were turned on. For the first hour, water and small amounts of ions were placed in the cells to ensure that all sensors were working. By noon, the Martian soil samples were put into the cells, stirred, monitored, and measured by voltage versus time. In order to collect samples, the Phoenix was outfitted with a robotic arm made of aluminum and titanium that allowed it to dig as far as half a meter deep into the icy soil.[3] A series of experiments were conducted in this manner for over 150 days, according to Dr. Kounaves.

> "The fact that perchlorate serves as energy source for bacteria makes the theory of past or future life on Mars plausible."

The WCL's first data collection was a major breakthrough for scientists and completely changed our view of Mars' geochemical history and its potential for supporting life. The primary analysis revealed a slightly alkaline soil of pH 7.7 and the presence of several ions, including Ca^{2+}, Mg^{2+}, K^+, Na^+, Cl^-, and SO_4^{2-}[3]. Most surprising to Professor Kounaves and his team, however, was the significant concentration of perchlorate found in the soil.

Based on past missions to Mars chlorine was known to be present in the Martian soil, but a wet chemistry experiment had never been done. Chlorine was expected to be found in the form of NaCl, yet when the soil was finally tested, $MgClO_4$ (magnesium perchlorate) was found. As Dr. Kounaves explained, this is significant because perchlorate is an oxidant; it is made up of four oxygen atoms attached to one chlorine atom. It is similar to nitrate (NO_3) here on Earth and serves as food or energy source for bacteria. This serendipitous discovery had substantial implications for both Mars and the Earth.

On Earth, perchlorate is used as an explosive and can be found in a number of products, including rocket propellants, paint products, and car air bags.[2] The discovery of ClO_4^- on Mars led Professor Kounaves to look back at soil samples from Antarctica's Mars-like environment. For the first time, perchlorate was identified across the Antarctic continent.

This was not discovered before because perchlorate is highly soluble in water and quickly consumed by bacteria, therefore only easily found in very dry areas. This discovery also brings up environmental and political controversy. For many years, perchlorate had only been found on populated continents, so it was believed that ClO_4 was solely produced through the use of explosives. As

Chemistry professor Samuel Kounaves designs Wet Chemistry Lab to evaluate soil on Mars, determines possibility of past or future life

a result of the WCL experiments, it was found that perchlorate is indeed produced globally in the stratosphere and deposited everywhere (but only accumulated in arid areas).[2] When members of the EPA tried to regulate ClO_4 production to 1 part per billion, they were in for a surprise; according to Dr. Kounaves, scientists had found naturally occurring perchlorate in 1000 parts per billion in Antarctica.

The fact that perchlorate serves as energy source for bacteria makes the theory of past or future life on Mars plausible. We know that water once flowed through Mars and that some bacterial spores can be dormant in dry, airless ice for hundreds of thousands of years.[4]

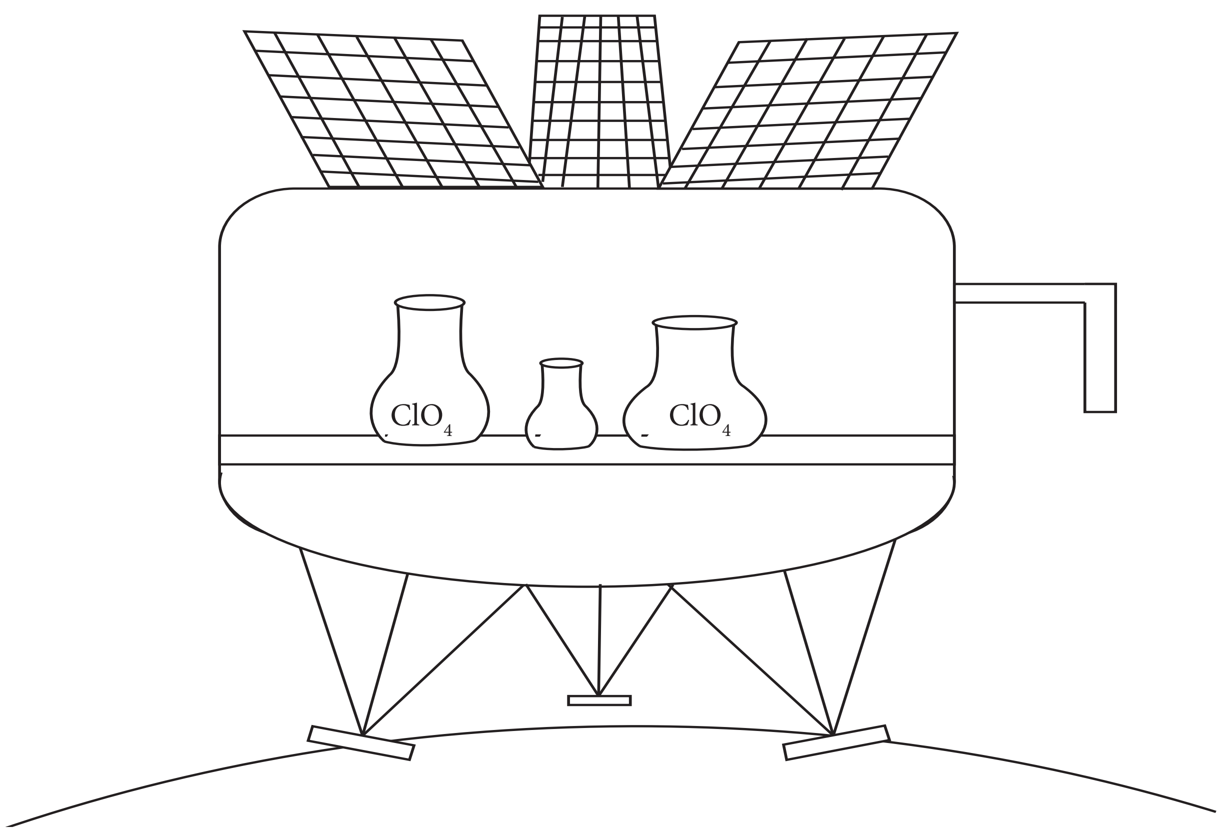
Even the pH and ions present in the soil suggest a suitable environment for sustaining life. Despite all these conditions, none of the past missions to Mars, including the Viking mass spectrometer experiments aboard the Phoenix, were able to discover any sign of organic substances in the soil. This lack of evidence can also be explained by perchlorate.

If just one percent of ClO_4 in soil is mixed with organic substances and heated to at least 300 degrees (the temperature at which the soil is analyzed), the ClO_4 oxidizes all of the organic compounds and forms CO_2 , Dr. Kounaves said.

Due to this property, new methods for analyzing soil at lower temperatures must be developed. At this time it is too late to change the current model in time for the next mission, and a future method will not be tested until the year 2018.

Story by Alice Haouzi, a freshman majoring in Biochemistry and Philosophy.

Spacecraft: The Phoenix Mars Lander **Launch Time: 5:26:34 a.m. EDT**
Launch Date: August 4th 2007 **Landing Site: Northern arctic plain, Mars**
Goal: Characterize and assess geology of Mars

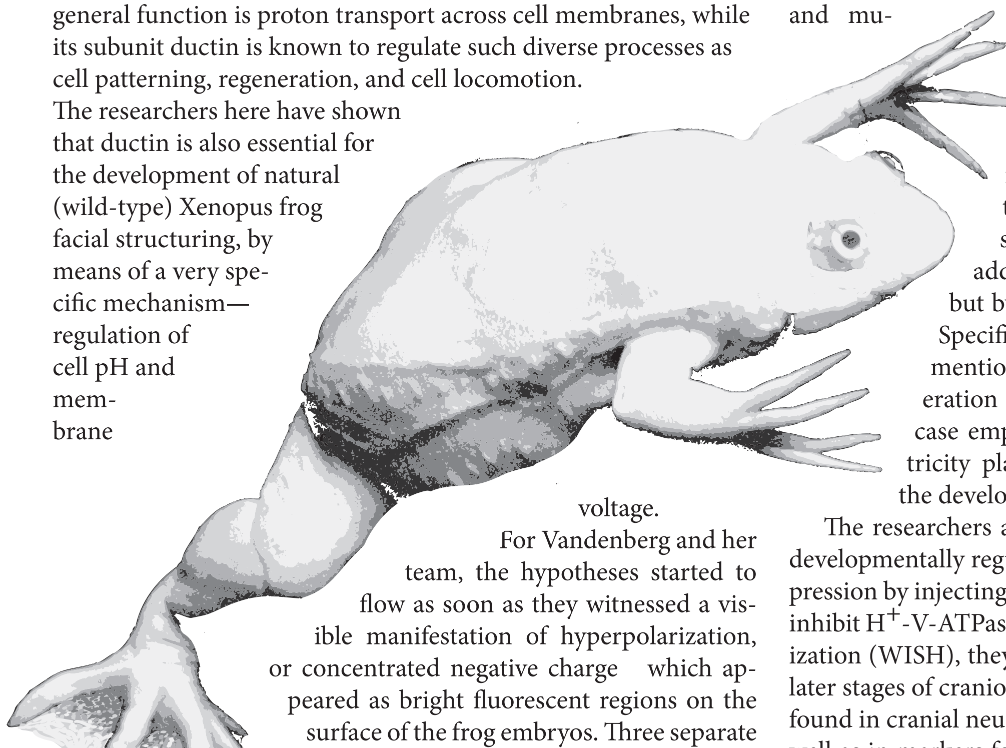


Visualizing Early Frog Development

Bioelectric patterns predict craniofacial structuring in Xenopus frogs

The Tufts Center for Regenerative and Developmental Biology, headed by Dr. Michael Levin, alumnus and professor of the Tufts Biology Department, produces research that integrates fields such as molecular biology, biophysics, and computer modeling. One section of the lab invests its time in studying the development of frog embryos and specifically how various stages of development are influenced by both genetic and bioelectric signaling pathways. As it turns out, these pathways present an opportunity for early onset disease recognition.

In their recently published paper, "V-ATPase-Dependent Ectodermal Voltage and pH Regionalization Are Required for Craniofacial Morphogenesis,"# released this past July in *Developmental Dynamics*, lead author Dr. Laura Vandenberg along with Tufts undergraduate Ryan Morrie and Research Associate Professor Dr. Dany Adams explore the relationship between bioelectric cell signaling and craniofacial patterning—referring to morphology in Xenopus frog faces. Ductin, a proton-transporting subunit of the proton pump H^+-V-ATPase, is the main focus of this article. H^+-V-ATPase is a highly conserved eukaryotic enzyme whose general function is proton transport across cell membranes, while its subunit ductin is known to regulate such diverse processes as cell patterning, regeneration, and cell locomotion. The researchers here have shown that ductin is also essential for the development of natural (wild-type) Xenopus frog facial structuring, by means of a very specific mechanism—regulation of cell pH and membrane voltage.



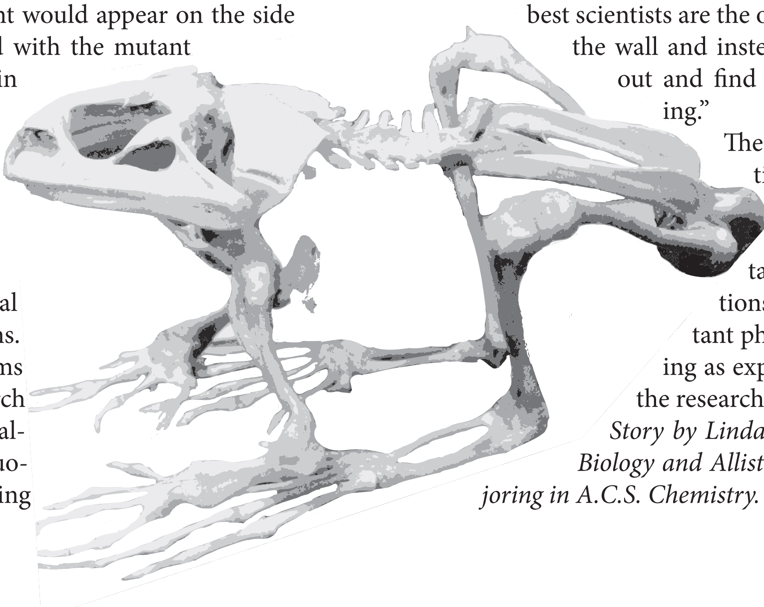
For Vandenberg and her team, the hypotheses started to flow as soon as they witnessed a visible manifestation of hyperpolarization, or concentrated negative charge which appeared as bright fluorescent regions on the surface of the frog embryos. Three separate courses of this bioelectricity were observed, distinguished by slight time delays.

First, in Course I, a non-selective wave of bioelectricity flashed across the embryo's surface, corresponding with the development of ciliated cells. Course II displayed the propagation of this bioelectricity in a site-specific manner, physically highlighting the regions in which specific craniofacial patterning would occur further along in development. These bioelectrical signals served as a pre-patterning and were accompanied by visualization of the expression of important genes controlling craniofacial patterning regions. Lastly, in Course III, another site-specific wave of bioelectricity was witnessed but, in this instance, it only affected the three-dimensional structure of the embryo from spherical to ellipsoidal. These directly observable phenomena both fired the research team's further investigation of the system and presented a potential opportunity for early defect recognition.

The observation was made during specific study of H^+-V-ATPase. This transmembrane protein regulates the proton flux for cells and, as a consequence, controls the voltage across the cell membrane. Vandenberg et al. were further focused on protein subunit, ductin, which is highly relevant as it is the portion of ATPase that directly regulates proton shuttling. Through a variety of ductin inhibition and mutation mis-expression experiments, its role was conclusively identified as vital to the healthy development of wild type craniofacial structure. Any variation in H^+ flux either above or below optimum levels led to craniofacial and otherwise developmental deformations as did mutation of the ductin subunit itself. Mutations were carried out not by directly adding toxins to disrupt native ductin subunits, but by adding mRNA coding for abnormal ductin. Specific mRNA was also utilized to induce the aforementioned H^+ flux variations by calling for the generation of alternative H^+-regulating proteins. Either case emphasized the critical role that ductin bioelectricity plays in maintaining proper morphogenesis—the development of shape in an organism.

The researchers also found that ductin is located upstream of developmentally regulated genes. To begin, they altered ductin expression by injecting an mRNA whose protein product is known to inhibit H^+-V-ATPase function. Using whole-mount in situ hybridization (WISH), they then probed for genetic regulators critical in later stages of craniofacial development. Abnormal expression was found in cranial neural crest markers at the start of neurulation, as well as in markers for parts of the eye and for brain development. As it is the beginning of the development of the organism's neural tube and nervous system, this neurulation is critical. Interestingly enough, they found that these abnormal WISH expression patterns had clear spatial correlations to the corresponding mutant phenotypes of those genes. For example, an abnormal ISH pattern for a gene involved in eye development would appear on the side of the embryo that had been injected with the mutant ductin mRNA, and would later result in a mutant eye phenotype in the developing tadpole. That ductin does indeed act as an upstream influence on ISH patterning was shown with seven different craniofacial regulatory genes.

For the authors, luck played a critical role in revealing the bioelectric patterns. Corresponding author Dr. Dany Adams was had been studying frogs in search of left-right facial pattern defects and altered tail regenerative ability using fluorescence, when she witnessed the flashing courses of bioelectricity in an overnight video. Vandenberg says, in advice to young scientists, "luck has a huge part to play in our ability to study cool biological processes that are of interest to us. The best scientists are the ones that come up against the wall and instead of giving up, they go out and find why things are happening."



The researchers are now continuing their study in this serendipitous vein, and it seems their work is taking them in new directions; progression of the mutant phenotypes is not proceeding as expected and, in the eyes of the researchers, that is just fine.

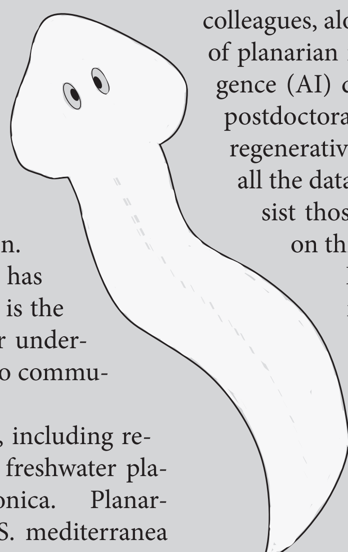
Story by Linda Le, a senior majoring in Biology and Allister McGuire, a senior majoring in A.C.S. Chemistry.

Also in the Levin lab...

Artificial Intelligence in Tufts' Backyard: *Planarian Stem Cells and Regeneration*

Just down the street from the main campus of Tufts University, Michael Levin, a professor in the Biology Department, and his team are conducting research on regeneration and stem cells with the planarian, a flatworm with the potential to teach researchers how to fight cancer.

Planarians are a model organism in terms of regenerative and stem cell research as a result of their successful regeneration using neoblasts. Neoblasts are a group of adult somatic stem cells and are the only cells that divide in the planarian. They can become any planarian cell, including germ cells, the reproductive cells in multicellular organisms. The planarian can regenerate a complete worm from a piece as small as 1/279th of the original worm1. Because planarians can generate from such a small piece, and because it is easy to isolate and manipulate the one type of cell that divides in the planarian, planarians are particularly useful in the study of regeneration. Learning more about how planarians regenerate has the potential to inform research on cancer, which is the result of "unpatterned growth," by expanding our understanding of the "molecular mechanisms cells use to communicate with one another."[2]



The Levin Lab is involved in multiple projects, including research on planarian self-regeneration3 using the freshwater planarians Schmidtea mediterranea and Dugesia japonica. Planarians have been studied for over 100 years. The S. mediterranea planarian genome has been mapped out, and researchers around the world are trying to figure out the regeneration patterns on a molecular level. Scientists have been able to create gene profiles and have identified proteins directly related to neoblasts.

Smed-SmB, a member of the LSm protein superfamily, has been "shown to be essential for neoblast proliferation and maintenance," in the research of Fernández-Taboada and colleagues.[4]

Through unraveling the transcriptome – the RNA molecules - of S. mediterranea, Abril and colleagues found out how transmembrane proteins regulate many biological processes, including cell signaling, which is important to regeneration and stem cell research5. They identified possible other factors that may explain how planarian neoblasts are regulated at the molecular level, including peptides, hormones and neurotransmitters, such as dopamine and serotonin.

These studies by Abril and colleagues, Fernández-Taboada and colleagues, along with research in the Levin Lab, and other studies of planarian regeneration, will be utilized in the artificial intelligence (AI) database that is being developed by Daniel Lobo, a postdoctoral fellow in the Levin Lab, to further stem cell and regenerative research1. The idea behind this project is to make all the data available to researchers everywhere as well as to assist those wanting to develop new experiments by drawing on this prior knowledge.

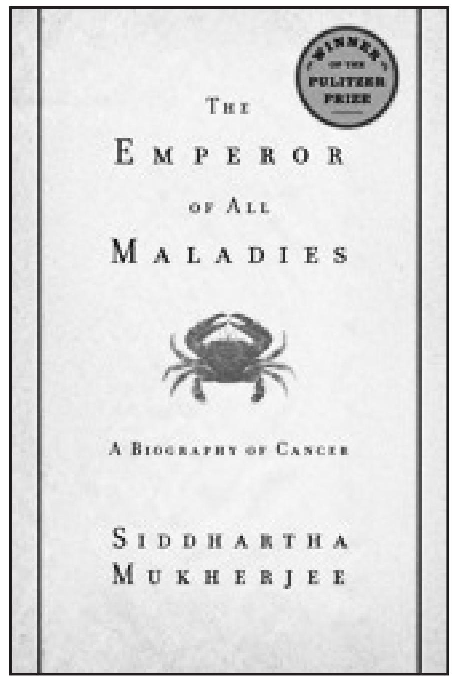
For the AI database to provide useful information, multiple components must be in place. There is the actual database of experiments, the AI module, and the simulation engine, all of which reflect the involvement of multiple scientists.

The AI database operates based on algorithmic models of planarian regeneration, developed from the database of actual experiments. It uses these models to create outputs of simulated experiments that are quantitatively comparable to the morphology results from the real life experiments that have been stored in the database. The planarian AI project is an effort to make order out of chaos, to find bigger patterns across multiple studies. *Story by Emma Marshall, a sophomore majoring in Biology.*

BOOK REVIEW:

An oncologist's coming-of-age

Review of *The Emperor of All Maladies: A Biography of Cancer*



COURTESY OF SIMON & SCHUSTER

Dr. Siddhartha Mukherjee was awared the 2011 Pulitzer Prize for General Nonfiction for his book The Emperor of All Maladies. Dr. Mukherjee is an oncologist and a professor at Columbia Medical School in New York.

The Emperor of All Maladies is a riveting tale that vividly outlines the history of a disease that has plagued mankind ever since it first appeared in written history over two millennia ago. This book is aptly subtitled *A Biography of Cancer* by its author, Harvard-trained oncologist Siddhartha Mukherjee. It is a biography in the truest sense of the word, as Mukherjee successfully portrays cancer not as the subject but as the antagonist of this story and explores the scientific, social and political developments that have defined the fight against cancer. The book delves into how cancer has affected the lives of historians, scientists, doctors and, most importantly, the patients themselves. As Mukherjee poignantly asserts, "All patients begin as storytellers, as narrators of suffering, travelers who have visited the kingdom of the ill."

Writing the "Biography of Cancer" would be an ambitious undertaking for the most prolific of writers, nevermind for a doctor writing his first book. But this story is as much about the disease itself as it is a chronicle of Mukherjee's own journey with respect to cancer.

As he puts it, the book is a product of "my coming of age as an oncologist," a way to maintain his sanity throughout the immersive training program in medical oncology at the Dana-Farber Cancer Institute,"an exploratory journey that carried me into the depths not only of science and medicine, but of culture, history, literature, and politics."

He explores cancer's past and present and outlines the possibilities which lie in the future. From the very first description of cancer on the papyrus scrolls of Egyptian physician Imhotep, to the advent of chemotherapy by famed pathologist Sidney Farber who dreamed of a "penicillin for cancer," to the modern breakthroughs in genetics which allow us to understand the mechanisms through which cancerous cells divide uncontrollably, this book is a comprehensive and yet undeniably accessible chronicle of the history of cancer not only as a disease, but also as a concept.

From our basic understanding of cell division as theorized by German biologist Rudolf Virchow, "Omnis cellula e cellula e cellula," to how the social stigma against cancer has evolved over centuries, Mukherjee conveys a wealth of information to his readers. And yet at its essence The Emperor of All Maladies is a story, an engrossing plot which chronologically traces the ever-changing nature of cancer and allows the reader to witness the progress of this malady through the eyes of academics, doctors, patients and society en masse.

Mukherjee began writing the book with one relatively simple ambition, as he explains: "I delved into the history of cancer to give shape to the shape shifting illness that I was confronting." Cancers in all their forms are illnesses that begin when a cell divides uncontrollably. Whether it be sarcoma, lymphoma, or blastoma, all cancers arise from this one microscopic abnormality.

Yet cancer is one of the most biologically diverse diseases in modern medicine. As the author writes, "Normal cells are identically normal; malignant cells become unhappily malignant in unique ways." Mukherjee's task then is a seemingly gargantuan one, to morph the multiple facets of this ailment into one coherent story. In The Emperor of all Maladies, he not only succeeds in this endeavor but simultaneously maintains the precision of a scientist, his curiosity as an oncologist, and the alluring tone of a best-selling author.

As "A Biography of Cancer," this is a story of relationships–the relationships between medicine and academia, doctors and their patients, and patients and their illnesses. Mukherjee narrates his candid reflections as an exceptional academic and oncologist, but far from being merely a work of popular science, The Emperor of All Maladies is a brilliant piece of non-fiction literature.

Review by Akshay Savlani, a freshman majoring in Biology and Philosophy.

Quotations taken from text of *The Emperor of All Maladies.*

OPINION:

GlobeMed:

Finding a niche to make change

In the Fall of 2011, Tufts University became part of a grassroots global health initiative that has been quickly spreading to college campuses across the United States. The core values of this movement made their way to the Hill with the founding of GlobeMed at Tufts, one of the chapters of the student-run nonprofit organization GlobeMed. The GlobeMed network is bound by its commitment to partner with communities in resource-poor countries in order to address their healthcare problems. By forming a strong partnership with a community, each chapter can focus their efforts into understanding their partner's problems and the social determinants that cause them.

Meet Peter Luckow, 25, co-founder of GlobeMed and a graduate of Northwestern University's Class of 2009. During his time in college Peter studied anthropology while taking pre-med courses to become a doctor. Wanting to combine these two areas to break down healthcare barriers, Peter sought to enroll in programs that would enable him to do work in impoverished communities abroad. One of these trips, he recalls, was a short-term project in Guatemala. In the end, it was not quite what he was expecting.

"Those week-long programs sometimes do more harm than good," he says. "They end up being volunteer-centric, as opposed to community-centric, and don't place as much of a priority on getting to the root of the community's problems. It felt like we were just dropping in and then dropping out."

Frustrated by his experience in Guatemala, Peter began questioning the strategies used to decrease healthcare disparities. "When we returned to Northwestern, we started to develop a humble model that focused not on the individual or their professional goals, but on what would most help the communities and tailor the projects to their best interests. We started looking for long-term partnerships so that we could focus our care."

With this vision in mind, Peter temporarily dropped out of Northwestern. He spent the next year co-founding and building GlobeMed. Initially, GlobeMed started off only as a "shared dream between a village in Ghana and a group of students at Northwestern University." These students saw a community suffering from extreme poverty and completely lacking access to healthcare. Determined to bring change to their village, Peter and his friends raised money through grants and donations and transformed an empty building in Ho, Ghana into a medical clinic with a pharmacy, pathology lab, nurses, and nutrition programs. To this day, the HOPE Center has been successfully maintained by the people of Ghana, with support and backing by the GlobeMed chapter at Northwestern.

Holding true to the values of the movement, GlobeMed at Tufts is currently developing a partnership with Nyaya Health, an NGO founded in 2007 that operates in Boston and works in Achham, Nepal. Achham, a district in the rural west of Nepal, was left devastated by a decade-long civil war that plagued the country until 2006. The conflict brought disparity to the communities and crippled the healthcare infrastructure. Similar to the inspiration that drove Peter's development of GlobeMed, Nyaya Health was founded by a Yale University medical student who travelled to Nepal and saw the "most harrowing healthcare situation he has ever seen." For the 260,000 people living in the area, there was not one allopathic physician and the only available hospital was hours away from the community. Since it was founded, Nyaya has worked in partnership with the local government as part of an initiative to rebuild the public sector health system in Achham.

In 2008, Nyaya began its efforts to provide free healthcare to Achham by renovating an old grain shed and turning it into a health clinic. Within two years, they moved their facilities to an empty building, establishing what is now known as Bayalpata Hospital. At Bayalpata Hospital, over 75,000 patients receive care each year, which includes x-rays, labs, and clinical visits. In an area where the average income is only 141 dollars per year, the people of Achham either receive free care or no care at all. Nyaya has managed to provide free healthcare to the community while also highlighting the socioeconomic and political factors underlying the existing problems. Though Nyaya has alleviated a significant part of the health burden in Achham, the mission is far from over. Their hospital and programs are still in need of long-term workers, higher-level resources, and more doctors. Most significantly, the hospital still lacks a surgical unit.

The GlobeMed chapter at Tufts University is partnering with Nyaya to help foster their development and strengthen their programs. In particular, GlobeMed at Tufts aims to enhance a critical component of their system: the employment of community health workers. These workers are primarily undereducated females that have received training by the Nepali government to offer basic healthcare in their communities. By following-up with patients and disseminating practical healthcare knowledge, these health workers serve as Bayalpata Hospital's liaisons to the community. In aiming to double the size of the community health worker program, GlobeMed at Tufts will be helping Nyaya reach more people to ensure that they are continuing to take care of themselves after treatment at Bayalpata Hospital.

Though a bold aspiration, the GlobeMed chapter at Tufts is in a unique position to help Nyaya given that it is the first and only chapter of GlobeMed to be located in the same city as the operations team that is behind Nyaya Health's organization and growth. By directly engaging the operations side of Nyaya, the Tufts chapter is hopeful that it will strengthen the coordination and growth of Nyaya Health, specifically through the community health worker program.

Story by Zach Silver, a senior majoring in Biology.

Construction of a Transcriptome

Graduate student Robert Burns' assembly of the mRNA sequences of the European Corn Borer

Graduate student Robert Burns is examining the genetics of the European Corn Borer (ECB), a species of moth whose genome we know very little about. He has constructed a transcriptome, which is the set of the mRNA molecules, to establish a basis of knowledge of the expressed genes in ECB.

Burns graduated from the University of Wisconsin, Milwaukee in 2010 with a major in biology and a minor in chemistry and joined the Dopman Lab at Tufts University in the fall of 2010. He is currently a second year doctoral candidate studying the source of genetic variation between two strains of ECB.

The European Corn Borer is a good study species because it is of interest to those in the fields of both agriculture and evolutionary biology. As an insect that feeds on many species of plants, it has become a major crop pest, causing billions of dollars of damage each year. From an evolutionary standpoint, ECB has two major strains that are in the process of separating into different species. Various gene flow barriers cause the divergence between the two types, the E strain and the Z strain. One of these barriers is the variants' differences in voltinism: one strain is bivoltine, meaning that it has one generation early and another late in the ECB season, and the other is univoltine, meaning that it has one generation in the middle of the season. This distinction means that the two strains of adults are present at different times during the year, with little overlap to interbreed.

PHOTO BY NOAH PAULSON

Robert Burns opens the incubator containing moth samples in the Dopman Lab.

Another impediment for reproduction between the two strains is a difference in pheromone blends. The female moths send out sex pheromones, a type of chemical breeding signal, to which the male moths respond. In turn, the males release their pheromones once in close range to which females respond. Z strain males are more attracted to the pheromone blends of Z strain females, and E strain males are more attracted to that of E strain female. The females of both strains are hypothesized to react in the same way. While this information is known about the behavioral aspects of ECB mating, very little genetic information is known about the European Corn Borer, a discrepancy Burns is attempting to change through his research.

He worked this past semester to sequence a transcriptome, a compilation of the sequences of mRNAs of different adult tissues. This mRNA is representative of only expressed genes, not all genes. In this case, the process of creating a transcriptome begins with smashing and grinding moth tissue. Since all mRNAs have a poly-A tail, magnetic beads with poly-T tails that base pair with the adenosine nucleotides were used to attract the mRNAs and separate them out. Reverse transcriptase was then used to make DNA out of the mRNA transcripts. The mRNAs extracted came from 22 different tissues: multiple larvae, pupae, and multiple tissues from adult male and adult female moths. Since mRNA consists only of expressed genes, separating samples by tissues and stages of life allows the examination of genes exclusively expressed in a certain life stage or tissue.

The samples were separated by Z and E pheromone strain, which allowed Burns to distinguish differences in expression between the two strains. After all the DNA was transcribed from the mRNA, he then had 22 different libraries of short read sequences that he needed to have sequenced.

Next-generation sequencing was chosen to sequence the DNA because it is cheaper and faster than Sanger sequencing. The downside to next-generation sequencing is that the sequences produced are short.

> "Our puzzle is composed of millions of pieces, and because we have no reference genome, there is no picture on the box to guide the assembly process."

The challenge in Burns' project was reconstructing these small fragments as the original sequences from the organisms. Burns compares a de novo transcriptome assembly to "putting together a large puzzle," since there is no reference genome. He describes that "next-generation sequencing technology yields millions of short sequences per run. Our puzzle is composed of millions of pieces, and because we have no reference genome, there is no picture on the box to guide the assembly process. Because thousands of different genes are expressed within a given tissue, there is not one puzzle, but thousands of different puzzles mixed together."

He used computer programs to help with this taxing process, looking for commonalities between sequences that overlapped in order to reconstruct the sequences. Burns has finished sequencing and assembling the sequences and can start to look at the differences between the strains.

Because the mRNA was separated from E and Z strain moths, the divergence between the strains can be characterized on a gene-to-gene basis. The transcriptome could be used to try to figure out what gene is responsible for the male pheromone differences. Burns describes the importance of the transcriptome: "Once published, the transcriptome will be a valuable resource for many different researchers working with the European Corn Borer…We can use our new wealth of genetic information to study the evolution of the traits that are working to keep populations separated."

Story by Julia Hisey, a sophomore majoring in Biology.

Faculty Profile:
Professor Kurt Pennell

Dr. Kurt Pennell, chair of the Department of Civil and Environmental Engineering here at Tufts, describes his research path as "a little atypical." He studies subsurface remediation, nanomaterials, and neurotoxicity. He investigates how contaminants enter the groundwater from their source and then develops technologies to clean them up. Some of his more recent research focuses on how these contaminants can contribute to neurodegenerative diseases, specifically the acceleration of Parkinson's disease. The progression from topic to topic is unusual, but logical.

> "The future of engineering is science...That's how you're going to make new discoveries and really make a difference."
>
> -Dr. Kurt Pennell

Dr. Pennell first became interested in environmental engineering because he liked math and science and enjoyed outdoor activities. His initial work was on herbicides and chemicals used in forestry, but he became concerned about the fate of those chemicals and whether they were harming the environment.

The research on neurotoxicity and Parkinson's disease began later, when Pennell was at a Muhammad Ali fundraiser in Atlanta. "One of my wife's friends works on Parkinson's, and he had this chemical that induced Parkinsonian-like features in animal models," he recalls. "It was an organic chemical that is used for organic farming called rotenone. So I became interested and involved." This involvement earned Pennell an NIH career award. His research on Parkinson's disease continues alongside site remediation consulting and the creation of new ways to remove toxic chemicals from the environment.

One of his current projects is the cleanup of Groyne 42, an area of the North Sea off the coast of Denmark, which is the most toxic site in the country. The primary contaminant at this site is pure parathion—an acutely toxic insecticide. Decades ago, a chemical manufacturing company was granted permission to dump its waste into sand dunes along the coastline. The waste seeped through the sand and entered the sea, leading to the deaths of many birds and fish. Chemical dumping stopped in 1962, but cleanup did not begin until 1971. Ten years later, after 1,200 tons of waste had been removed, it was covered with asphalt and sand. It wasn't until a storm in January 2000 that local authorities realized that the groundwater had been contaminated and that parathion was still leaching into the North Sea. To contain the toxins, large pieces of corrugated steel were driven into the sand—a process known as sheet-piling. This prevents the contaminants from flowing into the sea; however, salt water corrodes steel, meaning the system only has a lifespan of fifteen years.[1]

The sheet-piled wall gave experts time to develop a method to clean up the remaining waste. Because parathion is a liquid contaminant, it is held in the soil. The first step is to get the contaminant in solution. "I'm looking at surfactant injection there to get it to mobilize," says Dr. Pennell, who became involved with the project last fall and provides Geosyntec, the lead organization, with technical expertise and review. Surfactant molecules have a polar head and a nonpolar tail. When they align themselves, they form a micelle—a sphere with a hydrophilic shell and a hydrophobic core. The micelle's core attracts the contaminant, and its shell keeps it in solution. Once the parathion is in solution, the next step is to induce a chemical reaction. The current plan is to add sodium hydroxide to the contained area to initiate a chemical reaction. Pennell explains, "The idea is that you have it react in the ground, and then you can pump it out and treat it. It becomes much less toxic if you break it down one step, and then the product can be treated at a conventional industrial treatment facility."

Pennell also serves as an independent reviewer for the United Nations. He travels to Kuwait, where cleanup continues following the first Gulf War. The scale of this project is much larger than that of many sites in the United States; domestic spills of toxic materials are generally less than an acre, but Pennell describes this as "big, huge lakes of oil." He works mainly on the cleanup of recharge areas for groundwater, which must be cleaned up to a much higher standard. When asked how the site was progressing, Pennell responded, "Slowly!" The money to pay for the cleanup comes from Iraq, so the entire process is very politicized. "It's very complicated in that way," he says, "but it's very interesting."

Much of Dr. Pennell's previous research had been related to locating these types of organic chemicals in the environment and removing them, so the neurotoxicity research took those investigations one step further. "If you're just doing the cleanup, you never get to the point of what effect it has on humans or the environment," he says. "We developed all these technologies to clean things up, but no one really wants to use them. We could develop a great technology, but either it costs too much, or companies don't want to pay to clean up. So that's when I became interested in, 'Are we really making a difference?'"

The key to making a difference, in Pennell's view, is the integration of science and engineering. Environmental engineering, for example, is heavily rooted in chemistry, and that is what Dr. Pennell likes about it. Environmental engineers take chemistry and use it to solve problems. "The future of engineering is science," he says. "That's how you're going to make new discoveries and really make a difference." *Story by Ashley Hedberg, a freshman engineering student.*

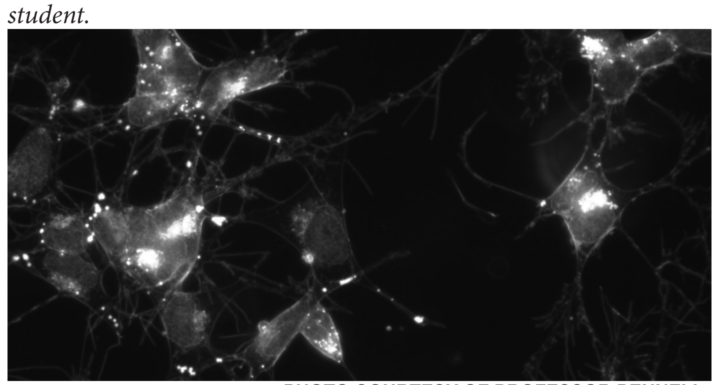


PHOTO COURTESY OF PROFESSOR PENNELL

An image of neurons studied by Dr. Pennell

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BREAKTHROUGH

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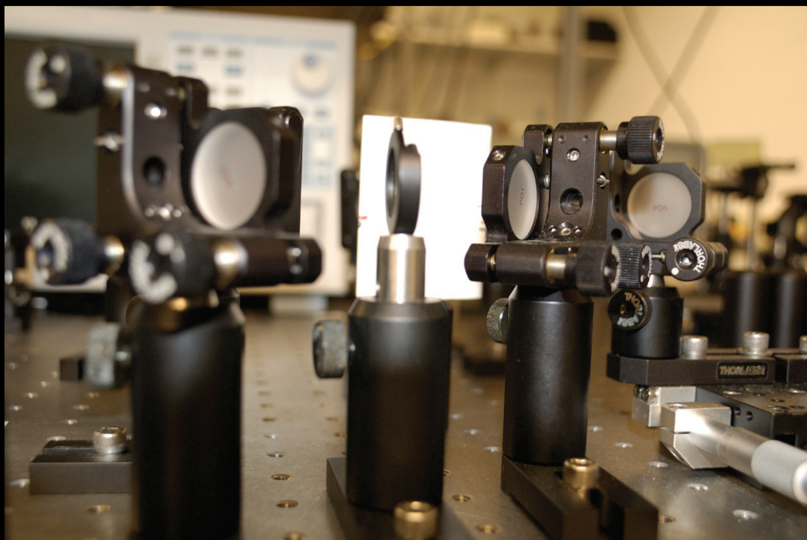
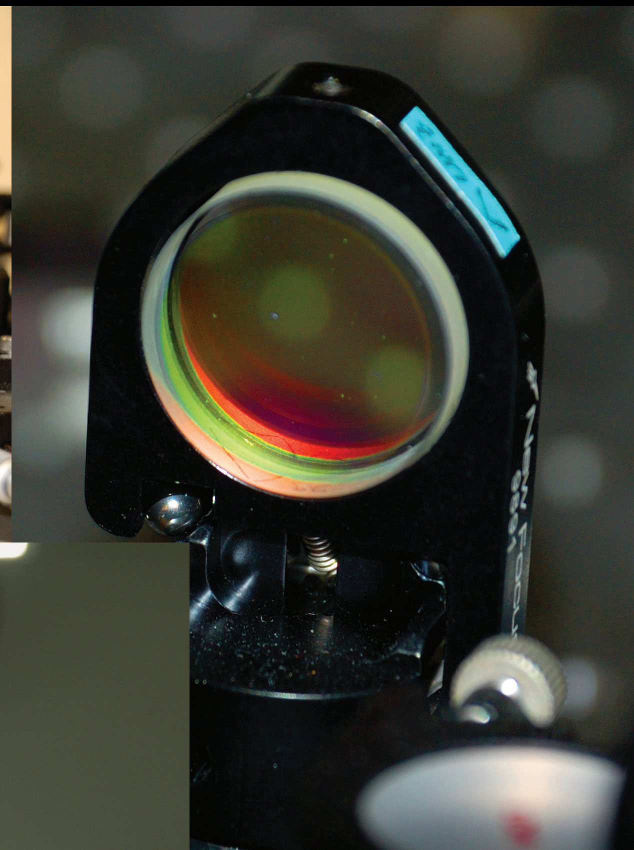
Ultrafast Nonlinear Optics and Biophotonics Laboratory

Biomedical Engineering Professor Fiorenzo Omenetto's groundbreaking silk optics research





CLOCKWISE FROM ABOVE: Lenses used to work with lasers in the Omenetto Lab; a laser-directing lens; silk bubbles; silk-derived optical materials; silk cocoons in Professor Omenetto's hand; a silk-derived hologram bearing the Tufts logo.

According to the Omenetto Lab website: "We study the use of silk as an optical material for applications in biomedical engineering, photonics and nanophotonics. Silk can be nanopatterned with features smaller than 20 nm. This allows manufacturing of structures such as (among others) holographic gratings, phase masks, beam diffusers and photonic crystals out of a pure protein film."

PHOTOS BY NOAH PAULSON