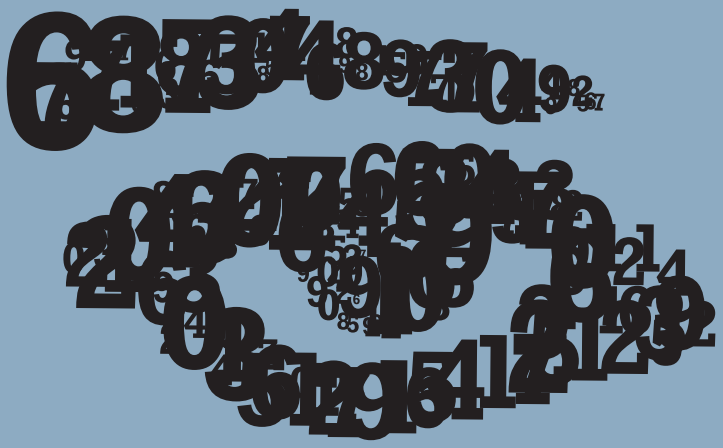
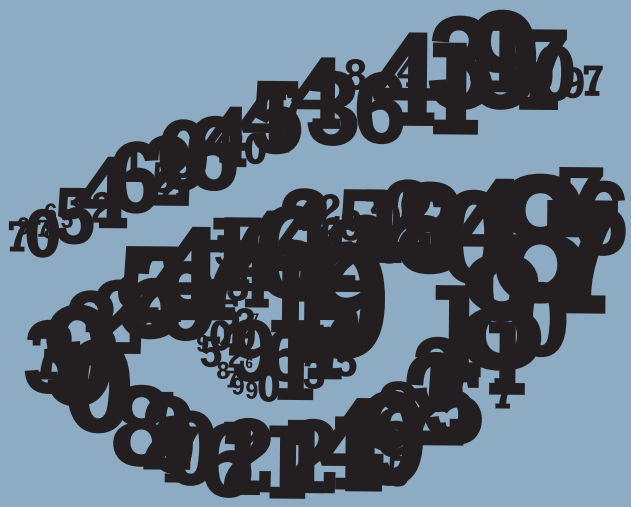
ISSUE 16

NUScience

Northeastern University's First Science Magazine





Always Watching

Big data has revolutionized the way governments and businesses interact with the public - but is everything as doubleplusgood as it seems?

Also inside:

- **The malleability of memory: Implanting false memories in mice**
- **Dr. Günther Zupanc on the possibilities of neurological regeneration**
- **Reinventing food production with 3D printing and GMOs**
- **Reducing the human sense of touch to 1's and 0's**

GET INVOLVED!

Are you looking for a creative way to showcase your work on campus? Do you want to boost your resume in a way that's creative, intellectual and fun? Become a part of NU Science! We publish two issues per semester on a variety of themes in science and technology and welcome our writers to explore any appropriate topic they find interesting.

We meet every **Thursday** at **8:15pm** in room **408 Ell Hall**. Come collaborate with us!

Letter from the Editor

Dear reader,

NUScience is happy to be back on campus for Issue 16, our first issue of the 2013-2014 academic year! This issue focuses on some of the amazing things that can be done in the world of science that may not quite fit with our society's morals and values. Just because we can do something, doesn't necessarily mean that we should … or should we? The articles that follow explore emerging technologies and ask questions not only as curious scientists, but also as human beings.

As a magazine, NUScience is currently making its own advances like never before. First of all, from now on the magazine will be in **FULL COLOR**! There's no controversy about how awesome this is. We have been waiting so long to bring you this and we are so excited to finally step up to the next level. Look at how great everything looks now that our graphic design team finally has the freedom to explore beyond the world of black and white!

Our membership has also skyrocketed and more writers than ever before submitted articles for this issue. To accommodate the increased volume of amazing content, we are now featuring additional articles you can't get in the magazine on our totally revamped blog! Check out NUSciencemag.com for more science news from our incredible student writers. We still welcome new members and encourage anyone who is interested to get involved and contribute to our magazine and blog!

This issue is also hugely exciting for me personally, as it marks the start of my first year serving as Co-Editor-in-Chief with Jess Melanson, and my last year at Northeastern. Being a part of this magazine has led me to pursue a career in science journalism and I am currently on co-op in that very field. I really am thrilled to be a part of something that is so spectacular and constantly improving, and I am thankful for everything it's done for me thus far.

Our goal with this issue is to provide the facts, present the controversy or discussion, and let you form your own opinions on topics in scientific and technological ethics. The right thing to do is to be informed, so I hope you read and enjoy this issue of NUScience!

Lauren Hitchings
Co-Editor-In-Chief, Biology, 2014

Read more at NUSciencemag.com

NUScience has made the leap to digital: Now you can read NUScience content throughout the year on our new blog at www.nusciencemag.com.

Upcoming pieces include:

- Scientists hope their mission to index viruses will go viral
- Eating disorders have long been classified as illnesses – but they may be genetic in origin
- New advancements in reproductive technology are making "designer babies" possible – but how far will that go?
- The human body responds to touch in curious ways

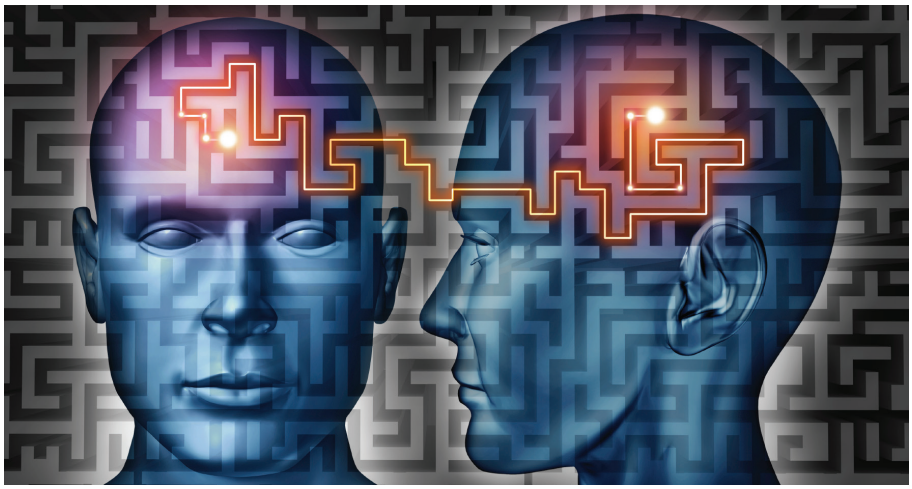
Mouse to Mouse and Mind to Mind

SHANNON JONES, MARINE BIOLOGY, 2016

Did you ever dream that you could read minds? Telepathy makes most people think of an old X-Men comic book, but when we add in technology, it becomes more like a gadget you'd find in a spy novel. Brain-computer interfaces, however, are currently possible, and are desired by groups worldwide. A brain-computer interface, or BCI, is a device that can allow a computer to read and decode a person's brain signals in order to infer the intentions and use machines to make that intention happen. This technology has practically limitless applications; doctors would benefit from access to patients who are in locked-in states, unable to communicate in any way or move their bodies; scientists would benefit from studying brain function in ways that have never been done previously; and soldiers would benefit from having devices that would allow silent communication between individuals and their home bases. Recently, several steps were made in the direction of achieving a BCI, culminating in the first humans to ever communicate brain-to-brain through a computer interface.

Several advances had to happen in order to make this achievement possible, the first being EEG technology. EEG stands for electroencephalogram, a kind of exam that studies the impulses in a brain. Most exams of this variety are done with transmitters stuck to the scalp with a sticky transmitting gel. Though this technology is not new, it has been improved in recent years to make it easier to use, more accurate, and more cost-effective. In order to test an EEG brain-computer interface such as this one, a game was devised in which a player had to shoot an arrow at a target in the center of the screen. Subjects aim by focusing on the target. A bar to the right of the screen indicated the focus level of the user on the target via BCI, and if the focus level was high, the shot fired close to the center of the target. The average accuracy score in a quiet environment was around 69.0%. This test was significant as it proved that an EEG could be used to monitor focus levels in real time, in order to control a computer game.

Another significant study was done on rats, which featured two rats' brains interacting through a computer. One rat acted as an "encoder", performing a task that required both sensory and motor capabilities, namely pushing the correct lever when it has a LED light lit above it. A computer transmitted the cortical activities of the encoder rat to a "decoder" rat, to see if the decoder rat could learn how to perform the same task correctly without outside help. Each rat was trained for their task, with encoder rats responding



to stimuli and decoder rats responding to cortical stimulation pulses. Then, when the experiment was run, the encoder rat saw the LED light, pushed the correct lever, and got a reward. The cortical activity of this task was transmitted to the decoder rat, which performed the task correctly and gained a reward a significant portion of the time. The encoder was rewarded as well when the decoder performed the task correctly to encourage the encoder to increase the quality of spatial information being transmitted. It was found that the more informative the pulses and the higher the frequency of pulses, the better the decoder rats did. This experiment shows that armed only with the transmitted cortical activities of the encoder, the decoder was able to make the same behavioral choices. In addition, there was no way the two rats could have communicated, because the test was run again with the decoder in Durham, North Carolina and the encoder in Natal, Brazil. Despite this extreme distance, the rats were able to perform the task correctly.

The same researchers also used their encoder and decoder rats in order to test if the rats could communicate a sense of touch. The encoder mice were taught to determine whether the size of a space in the side of their cages was narrow or large, then to poke the left side of the space if it was narrow and the right side if the space was large. This experience was transmitted to the decoder rats in a similar way as before, with only the cortex activity (sense of touch) of the encoder transmitted to guide the decoder in what actions to take. Once again, the decoder mice performed the activity correctly a significant amount of times. These experiments showed that it was possible to establish a real-time artificial communication link between two brains, which could then be used to make informed choices about what behaviors to adopt. These experiments proved the possibility of a direct brain-to-brain interface that allows communication in real time.

A research team at the University of Washington carried this brain-to-brain interface one step further on August 12, when they performed a similar brain-to-brain link with two of their professors. This experiment was performed using computer game in which the players had a narrow window of time to "fire a cannon" and "save the city from pirates." The sender, transmitting EEG signals in live time, watched the game, and, when it was time to fire the cannon, imagined pressing down his finger. The receiver wore a noninvasive magnetic field that stimulated his brain, called Transcranial Magnetic Stimulation, or TMS. This allowed the transmitted cortical information to be used to stimulate the brain directly, but without direct stimulation or electrical pulses. When the sender imagined firing the cannon, the receiver's hand jerked upwards involuntarily and came back down on the space bar of a computer, firing the cannon. The direct brain-to-brain transfer of information in humans has now been proven possible to use in simple, cooperative tasks.

Much more testing is needed to expand our knowledge of how brain-to-brain communication and brain-computer interactions can become useful and integrated with our society. Larger-scale human tests are likely the next subject of study, though it will probably be a long while before any device of this sort is introduced to the public. For now, we can only dream about the possibilities of clicking open our favorite sites without a mouse or communicating how to do tasks without words. It's too bad the technology won't be in place for your next class presentation! ■

Prosthetics Users Get the Upper Hand

BY JOE ZIMO, MECHANICAL ENGINEERING, 2015

The human arm is a marvel of uneasily matched proportion. It allows us to build and write. It allows doctors to save lives and loved ones to embrace. It is a part of the human body that is used every day for innumerable functions. Making the lives of those who have lost an arm easier is something that Dr. Todd Kuiken is focused on. Working from Chicago's Northwestern University and The Rehabilitation Clinic of Chicago, Dr. Kuiken is a pioneer of Targeted Reinnervation: a technology that surgically grafts a patient's severed nerves to local healthy muscles. The prosthetic functions by sensing a signal from the healthy muscles and simultaneously activating a preset function, thus allowing an amputee to operate a prosthetic limb by "thought".

Former Army staff sergeant Glenn Lehman lost his right arm in Iraq from a hand grenade. Working with Dr. Kuiken, Lehman has been fitted with an advanced prosthetic allowing him to accomplish many tasks that an individual lacking a limb would find impossible. When asked for a demonstration, Lehman was able to pick up and bounce a ball, drink a cup of coffee, and catch a light cloth.

> "I can raise them lower the elbow, I can rotate the hand, so it's in our out. I can open and close the hand, and I can flex the wrist either in or out. Those movements were all controlled by me, thinking about my phantom limb."

"I can raise, then lower the elbow. I can rotate the hand, so it's in or out. I can open and close the hand, and I can flex the wrist either in or out. Those movements were all controlled by me, thinking about my phantom limb," Lehman explains. The actions he describes can be done instantaneously and simultaneously, a feat only possible because of innovations in the last five years. Previous attempts at direct control of prosthesis allowed for only two motions (referred to as degrees of freedom, or DOFs) and these could not be performed at the same time. Lehman's prosthetic arm allows for five degrees of freedom, and he can perform any combination of them at once. At the time of his demonstration, Lehman had been fitted with the arm for a mere two weeks. The device, attached to Lehman's remaining upper arm, has the outward appearance of a typical human appendage. It has an elbow, a wrist, and a hand, all in seemingly regular proportion and function.

Targeted reinnervation is a technology that many will utilize. According to Martin Baechler, the surgeon who attached Kuiken's technology to Lehman's arm, "the performance of the surgery is actually very simple. The anatomy is predictable and the procedures of transferring the severed nerve to a healthy piece of muscle is quite simple." Targeted reinnervation has even been found successful in young patients who lost limbs as many as ten years ago.

The final frontier for this technology is finding a way for a recipient to feel and touch everything just as their prosthetic does. Kuiken believes it is possible and has even had some success in his research through the use of sensors and signal transmission. The effects of this technology have the possibility of opening up an entirely new pathway of science and innovation. At one point merely a token of science fiction, the idea of human enhancement is now far from unheard of. Is it possible to develop a "better" human arm? A healthy human hand contains five digits, and not a single USB drive. This didn't stop Jerry Jalava, a Finnish programmer, from replacing his lost ring finger with a silicone replacement containing a removable 2-gigabyte stick.

There are also cases of individuals having earth magnets placed under the skin of their fingertips. This procedure allows them to feel the magnet's slight oscillations in response to electromagnetic fields. The result? – the ability to pick out live electrical cables by "feel". A combination of these explorations and Dr. Kuiken's breakthrough technology could be the start of a torrent in the field of modern bionics, the result of which is limited only by imagination. One day, the ideal prosthetic arm might look nothing like a human arm, forgoing naturalness for efficiency and increased function. Is this even possible? Time will tell. ■

Sensitive Robotics

BY JORDYN HANOVER, BEHAVIORAL NEUROSCIENCE, 2017

Scientists have been working with robots for over 50 years, and within the last five, robotics labs have been working on a technique that would create a robot with a human-like arm. Sensitive robotics is a field that works to create robots with the same levels of sensation – particularly touch – as humans. Researchers at Georgia Tech, Emory University, and Massachusetts Institute of Technology, as well as scientists in the European Union, have successfully created robots that use their different sensors to respond to properties of objects being manipulated.

One of the most important aspects of the developing technology is the concept of haptic feedback – essentially machine communication through touch (vibration or pressure) to indicate the commencement or completion of a certain process. When a cell phone buzzes at an incoming call, for example, it creates haptic feedback, since the phone is signaling to its owner by touch that he or she has a call.

Professors sponsored by the European Union used tactile feedback to create a robot that has the same sensitivity as human skin. Electric sensors acted as receptive fields for touch sensations (similar to the nerve network of touch in humans, which detects various pressures, as well as temperatures) and software built into the robot to process the incoming data. Called ROBOSKIN, this model, in development since 2008, focused on classification of touch and pressure. Due to the difficulty of the final project goal, building a cognitively aware robot, this first step in creating a robot that can "touch" will assist in further research in sensitive robotics and robotic cognition.

Researchers at MIT's Computer Science and Artificial Intelligence Lab developed a robot with similar functions as the ROBOSKIN model, but with a different approach. Inspired by the anatomy of the human hand, developer Eduardo Torres-Jara built a robotic hand, which essentially functions the same way. The Obrero robot has three fingers attached to a palm, with several variations of sensors, including tactile, force, and position. Torres-Jara stated in an interview with Boston.com that he is building an entire arm that can essentially sense and act as a human arm, and can not only navigate a laboratory but also assist other PhDs in their experiments throughout the night without installing a camera that could act as the robot's eye.

> "Another, similar robot called RIO is already working with surgeons on knee and hip surgeries."

Cambridge Research and Development is also working on a prototype device that would allow surgeons to be more precise in surgery. These robots, called Neo, would allow surgeons to receive slight pressures on their hands when Neo indicated that a suture was being pulled to tight, or a surgeon was gripping an area too tightly or in a way that could cause complications and damage. Another similar robot called RIO is already working with surgeons on knee and hip surgeries, using previous data compiled about the patient so that if a damaged area is pushed too hard, the robot will alert the operator that their actions are harming the patient. With the explosion of recent developments in the field of sensitive robotics, it is clear that scientists have many different visions for the functions of these robots that can "feel."

Researchers across the country and world are developing technologies that build upon previous discoveries and improve with each additional study. Within the last year, the director of Georgia Tech's Healthcare Robotics Lab, Charlie Kemp, announced that they had successfully developed an entire arm similar to Torres-Jara's vision. The arm has a control method that works with robotic joints as well as the same type of tactile sensors that the ROBOSKIN project worked on and developed several years before. The robotic arm has been tested in several situations and has displayed several of the capabilities of a human arm, including movement through tight spaces and acting as an assistant robot for a volunteer with quadriplegia, who praised the robot's capabilities, such as bringing him a towel to wash his face. The robot is also considered a touch-sensitive device, which indicates that it can use its sense of touch to navigate its surroundings and decide upon a course of action. Kemp views this as indicative of what the future holds for robotics technology in terms of Healthcare – his robot was developed with the capability to, for example, retrieve pills for someone who may not be able to do so themselves.

Sensitive robotics is a quickly growing field. As the number of researchers in the field focused on ways to improve this technology climbs, sensitive robotic functions in society will increase. Through the increase in successful robotics programs, scientists will be able to use their creations to improve the quality of life for many people, from successful surgeries to helpful robotic home care assistants. ■

Uncovering Tamu Massif:
Earth's Largest Volcano

BY NOLAN CARR, BIOLOGY, 2015

Approximately 1,000 miles east of Tokyo, 6,500 feet below the surface, covering a whopping 120,000 square miles of sea floor, is the newly discovered volcano, Tamu Massif – published in Nature Geoscience on Sept. 6, 2013. Tamu Massif covers roughly the same amount of land as New Mexico. What is particularly fascinating is not just its size, but its shape. Tamu Massif is a shield volcano, meaning it developed by constantly forming new layers of lava to give it its broad shield shape. It only rises a few kilometers above the sea floor, which explains what took lead author and University of Houston geophysicist William Sager so long to find that the formation he and his team uncovered 20 years ago was produced by a single apex. It was surprisingly not made up of numerous volcanoes as previously conjectured.

Scientists have compared the volcano to Olympus Mons, another shield volcano on Mars. Although Tamu Massif may have Mons beat on sheer land mass covered, Tamu Massif doesn't come close to Olympus Mons's peak at 14 miles above the surface (for comparison, Mount Everest tops out at roughly 5.5 miles). So while claiming Tamu Massif could be the biggest volcano in the solar system may appear misleading, it shouldn't detract from the fact that Tamu Massif has pushed the boundaries of scientific knowledge on what is geologically possible here on Earth.

Core samples and seismic reflection data collected between 2009 and 2012 were able to help the scientists pinpoint the summit and trace thick lava flows that surged down slopes for hundred of miles during the end of the Jurassic Period. Interestingly enough, Tamu Massif was formed 145 million years ago as part of the Shatsky Rise underwater mountain range, but was active for only a few million years after, a relatively short time geologically. This is a testament to the massive amounts of magma Earth's mantle is capable of casting out, valuable information as geophysicists like Sager further attempt to construct a model of Earth's inner mechanics: mechanics that influence seismologists studying earthquakes and Tsunami's offshore, to Geochemists studying volcanic products that could affect marine life. Sager and his team now have their sights set on exploring the Cobb-Eickelberg Seamount chain in the Gulf of Alaska where they suspect there may be similar formations waiting to be uncovered. ■

The Plastisphere:
A New Frontier

BY EVANGELINE FACHON, BIOLOGY, 2017

We live on a plastic planet. The packaging for our food, the clothing we wear, the casing on our smartphones; all of these are symptoms of a global plastic addiction. This synthetic material somehow influences every aspect of human life, yet plastic is a relatively recent innovation. It was first invented in 1862, but wasn't widely used in commercial applications use until the twentieth century. Many plastic products are disposable, designed to be used once and then thrown out. Astounding amounts of these products never make it to the landfills. Instead, plastic litter can be found almost everywhere in nature, and most of all, in the ocean environment. Once in the water, plastic can begin to break down into increasingly smaller pieces, yet it never biodegrades completely. Every piece of trash that goes into the ocean today will still be floating around hundreds of years later; this is because bacteria don't metabolize plastic the way that they do other organic materials.

Since this is a relatively new problem, scientists are still developing ways to assess the long-term impacts of plastic on the ocean and its ecosystems. While people are still trying to find sustainable ways to fix the plastic problem, nature has begun to develop its own solutions. In a recent study, entitled "Life in the 'Plastisphere': Microbial Communities on Plastic Marine Debris," scientists Erik Zettler, Tracy Mincer, and Linda Amaral-Zettler reported findings of bacteria that have adapted to live on a plastic environment.

These unique ecosystems contain multiple species of microbes, varying in size and shape. After examining samples from a diverse set of locations, over fifty different forms of bacteria were observed. These communities were biologically separate from the seawater that they lived in, with entirely different organisms found to be present in the surrounding water than on the plastic debris. Bacteria present on the plastic were analyzed through a variety of techniques, including DNA analysis and examination through a scanning electron microscope. In a press release from the Woods Hole Oceanographic Institution, Amaral Zettler said, "We're not just interested in who's there. We're interested in their function, how they're functioning in this ecosystem, how they're altering this ecosystem, and what's the ultimate fate of these particles in the ocean."

Perhaps the most exciting finding from the study was a spherical shaped bacteria, which images showed to be embedded into indents in the surface of the plastic. These holes in the substrate surface indicate that these organisms may possibly be metabolizing the plastic, helping it to break down more quickly. While more studies on the form and function of these microbes are necessary, these preliminary results could forecast a brighter future for our oceans. If more can be learned about these new ecosystems and how they work, then perhaps these discoveries can be used to help clean up the oceans. ■

Northeastern's Marine Science Center Continues to Grow with Ocean Genome Legacy

BY KATIE HUDSON, MARINE BIOLOGY, 2017

Twenty-five minutes north of Northeastern University's main Boston campus lies a small island, connected to the Massachusetts mainland by a narrow, two-lane highway. The island of Nahant has one main road, two convenience stores, and an old military bunker dating back to World War II. This bunker is no longer in use by the U.S. Military; instead, it has housed Northeastern's Marine Science Center since 1968. This center is the main headquarters for the Marine and Environmental Science Department, formally known as the Earth and Environmental Sciences Department.

The facility is in the final stages of completing a multimillion-dollar expansion, adding new classrooms and research space to the campus's main building. This added space will give the Marine and Environmental Department room to expand as they hire new faculty in the coming years. Marine Science Center Director Geoffrey Trussel recently said in an interview that he plans to add up to 14 new faculty members to the space in the coming three to five years.

In July 2013, the Marine Science Center completed a deal to expand the facility further thanks to donations from New England BioLabs and multiple private donors. The center made this new deal with a group known as the Ocean Genome Legacy, a nonprofit organization dedicated to cataloguing the vast genetic diversity of the ocean's organisms.

Since 2001, Ocean Genome Legacy has been working protect the information located in the genomes of the ocean's rarest, most endangered, and most important species. The project was created as a result of global biodiversity loss due to global climate change and the numerous impacts the human race has had on the oceans. To do this, the Ocean Genome Legacy developed the Ocean Genome Resource, a genomic library including tissue, DNA, and RNA samples. This library is not limited to genetic data – it is expanding to cover taxonomic and ecological data about each species as well.

The information located within these samples is catalogued in a public-access online database for the use of researchers, public outreach and education groups, and the general public around the world. The Ocean Genome Resource is also connected to the Encyclopedia of Life and the Ocean Biogeographic Information System – both online databases available to the public. The entire library of samples is open to any researchers who wish to study the specimens at no cost to the researcher. All researchers are also allowed to contribute to the Ocean Genome Resource as long as they follow the Ocean Genome Legacy's policy of fair and ethical trade and collect samples in a sustainable manner without damaging local ecosystems.

By moving to Nahant, the Ocean Genome Legacy looks to continue to expand its genetic library with the help of Northeastern's faculty and students, who will be able to collect new samples in the multiple marine habitats located around Nahant. The facility will expand into a new lab space in the coming years to house the collection as it continues to grow. The space will be available to any visiting researchers who wish to study the collection. This will increase the number of researchers visiting Northeastern's Marine Science Center each year, extending the facility's growing network.

The Ocean Genome Resource will become a major research focus for the Marine Science Center, as well as a focus in the classroom and in the center's outreach programs, according to College of Science Dean Murray Gibson. Gibson recently said of the collaboration between the Ocean Genome Legacy and the Marine Science Center: "The collection becomes a focus for our research, education, and outreach, and through this partnership we aim to accelerate the fulfillment of the goal of OGL–to preserve DNA samples from all the ocean's species."

Ocean Genome Legacy and Northeastern University both have said that they believe that this data will be used as not only a resource for genomics and marine research, but will also serve as a baseline for marine conservation studies. Currently, a solid, common baseline does not exist in conservation sciences. This database will give conservation scientists a baseline to compare research to, allowing them to determine if conservation efforts are successful.

The Ocean Genome Legacy and the Ocean Genome Resource is predicted to move to Nahant sometime during the fall semester. Northeastern will not only be able to assist in the collection of this groundbreaking research once it arrives; faculty and students will also be able to learn from it as the collection grows via research collected across the globe. Northeastern will also benefit from this collaboration in other ways. The relocation of the Ocean Genome Legacy to Northeastern will draw many renowned researchers to the Marine Science Center to study the Ocean Genome Resource's collection of samples. These researchers will bring their own research and ideas and help Northeastern push the boundaries of research and knowledge further. The addition of the Ocean Genome Legacy to Northeastern's plethora of resources will only increase Northeastern's momentum at the Marine Science Center and across the university as a whole. ■

Photo courtesy of Northeastern Science Flickr

Growing Up in Space: The Effects of Zero-G on the Human Body

BY ANDREW BLOY, BIOLOGY, 2017

As humanity continues to explore the vast reaches of the universe, it is possible that sometime in the distant future, humans will colonize space. Colonies in space would mean babies in space–which raises a very important question: How well suited is humanity to survive and reproduce in space? How would babies who are conceived and born in space be different from babies born the old-fashioned way on Earth?

To understand this, first look at today's astronauts who spend extended periods of time in space. Experiencing Zero-G wreaks havoc on organ systems that have evolved over millions of years to become optimized for Earth's gravity. Everything from bone density and blood circulation to the inner ear's ability to aid balance are all finely calibrated to operate under normal gravity.

The body responds to a Zero-G environment in a variety of ways, the first of which is known as space adaptation syndrome (SAS). Also called "space sickness," this illness–which affects over half of all astronauts–is essentially the extreme space equivalent of becoming seasick or carsick, caused by changes in motion and the ways sensory organs perceive the surrounding environment. While on Earth, the human body gets accustomed to the way the senses perceive the world. In space, the brain becomes confused because the sensory organs barrage the brain with signals that would be contradictory on Earth but are perfectly normal in space. For example, the eyes may perceive that the body is floating upside down. But without any G-force applied to the body, the vestibular system in the inner ear cannot determine which way is up, causing contradictory signals to be sent to the brain – often resulting in severe nausea. The vestibular system functions by determining where the fluid of the inner ear settles in a system of canals. On Earth, this system is excellent for determining motion and orientation, but in a Zero-G environment, the inner ear fluid floats freely around the canals, rendering the system useless.

Space experience has been limited to adult humans accustomed to Earth's gravity. If a human were born and raised entirely in a Zero-G environment, what might be the result?

In a study performed at the New York University School of Medicine, scientists compared rats that matured in space with rats raised on Earth in terms of their ability to right themselves and move around in an environment with normal Earth gravity. The rats that matured on Earth were much better at maneuvering under normal gravity than the rats raised in Zero-G. The rats from Earth experienced gravity during the development of their motor systems, giving them a distinct advantage over the other rats. If rats raised on Earth are better at accounting for gravity than Zero-G-accustomed rats, could the same apply for humans? If their motor systems developed without the presence of gravity, would humans develop to the point that they could interpret vestibular system signals unambiguously?

Even if sensory perception in space could improve by developing in Zero-G, other health issues present serious issues. For example, consider the astronauts' loss of muscle mass and bone density during their missions. In a Zero-G environment, the stress on the muscles and skeleton from maintaining posture is absent, causing muscles to atrophy and bone density to diminish. Most of this loss of muscle and bone mass occurs in the legs, because they wouldn't be used for locomotion. In just five to 11 days, astronauts can lose up to 20 percent of their total muscle mass. Bone degradation occurs at a slower rate, with only 1.5 percent of total bone mass lost each month. However, after a typical four- or five-month trip to the International Space Station, it can take an astronaut two to three years to regain all of his lost bone density. Without frequent and vigorous exercise, the muscle atrophy and osteoporosis can become much more severe.

If a human were born in space, it is unlikely that a strong bone and muscle structure would ever develop. As astronauts have shown, frequent exercise can help fight some bone and muscle loss, but no exercises can completely replace the constant and powerful effect that gravity has on a body. Without ever experiencing the need to walk, children born in space could grow up with withered legs, looking like they had a severe form of Ricket's Disease. It is unlikely that children born in space would ever be able to walk on Earth.

Humanity will continue to explore. While it may seem like colonizing the final frontier is the future, there are still many obstacles for medical science to overcome before infant astronauts can float alongside their adult counterparts in the International Space Station. ■

Back to the Moon:

LADEE the Explorer

MEGAN PINAIRE, MARINE BIOLOGY, 2017

The 20th century is known for space exploration: think the Space Race between the Soviet Union and the United States, the first man on the moon in 1969, and the most recent human exploration of the moon in 1972. The 21st century, however, is giving way to more high-tech robotic exploration. Some of this technology may have the potential to solve a mystery that dates back to the last time humans walked on the moon: What caused the pre-sunrise glow that the most recent Apollo astronauts saw? Sending robots to the moon could also help NASA gather data about the fragile lunar environment before further future human activity disturbs its surface.

On Sept. 6, NASA's Lunar Atmosphere and Dust Environment Explorer launched from Wallops Flight Facility in Virginia. The 844-pound robotic explorer, familiarly known as LADEE, departed on a 160-day mission to gather information on the moon's atmosphere, surface conditions, and environmental influences on lunar dust, so that scientists can develop a better understanding of the moon's thin atmosphere. Scientists already know that the moon's atmosphere is actually an exosphere, which means the molecules that make it up are so spread out that they do not collide. Planets such as Mercury have exospheres as well – so retrieving more detailed information from the moon during this mission will also help educate scientists about other space bodies such as planets and their respective moons.

LADEE's overall mission is divided into sections. Once launched, the spacecraft will enter different phasing orbits, ensuring the robot lands on the moon at the correct time. After a three-minute Lunar Orbit Insertion, LADEE will experience 24 hours of an elliptical orbit. After these 24 hours, LADEE will perform more maneuvers to reduce the orbit to a circular, 156-mile trajectory. These maneuvers and orbit insertions make up the approach phase of the mission.

The next phase of the mission is the science phase, which will last 100 days. LADEE will orbit the moon at an altitude ranging between 20 and 60 km. These differences in altitude accommodate the moon's varying and uneven gravity.

LADEE has three main scientific instruments on board: The Ultraviolet and Visible Light Spectrometer (UVS) analyzes light signatures of substances and materials found by the explorer to determine lunar atmosphere composition; the neutral mass spectrometer (NMS) measures fluctuations in the lunar atmosphere as the moon orbits around the earth; and the Lunar Dust Experiment (LDEX) gathers and studies thin atmospheric dust particles. LADEE also has a contemporary, quick method of communicating results to scientists back on Earth. The explorer will use lasers to communicate scientific data and analysis, which have a down rate travel rate of 622 Mb/s. This is much faster than the radio waves used by past missions, which had a rate of only 100 Mb/s. Lastly, a decommissioning phase will ensue, and LADEE will land on the surface of the moon.

In the past, most robotic explorers were made using custom designs. Such a strategy is very expensive, so instead, LADEE was produced through a contemporary assembly line. In this line, a basic design is used for all explorers, and then the factory can make minor custom modifications specifically for the robot's mission. LADEE's body is the Modular Common Spacecraft Bus body. This assembly line production of space robots is cost-reducing, similar to Ford's assembly line of motor vehicles. The launch of LADEE is an incredible opportunity for scientists to continue the age of space exploration – and there are high hopes that it will answer the question of whether electrically charged lunar dust caused the pre-sunrise horizon glow that the Apollo astronauts observed over 40 years ago. ■

Photo courtesy of NASA

A special tribute to the Space Frog:

A poor, probably very large, and almost certainly deceased frog was caught in a single frame of a remote NASA camera during the Minotaur V launch carrying LADEE to the moon in Virginia's Wallops Flight Facility. The frog's spread eagle pose can be attributed to it being quite startled by the sudden and high-speed blast. What was our froggy friend doing there? The flight facility is located on an island that is mostly covered in marshlands, presumably where the frog resided until choosing the wrong day to go exploring on NASA's launch pads. Perhaps he was aspiring to join his few famous relatives: Frogs that have actually traveled to space for research on motion sickness and weightlessness in zero-gravity environments!

Memory Modification Becomes a Reality

BY NAOMI STAPLETON, PSYCHOLOGY, 2016

Photo courtesy of Novatis AG

No longer the stuff of nightmares, horror films, and science fiction; memory manipulation is now a reality for some highly confused lab mice. Scientists at MIT recently made animal subjects believe they had experienced nonexistent events, demonstrating the possibilities of brain therapy through memory modification.

Combining genetics and optics, the revolutionary field of optogenetics has introduced an entirely new field of brain study to the scientific arena. By targeting light-sensitive proteins at particular cells in living tissue, and delivering light deep into organisms via optical fibers, these highly precise techniques could transform how scientists study the brain. The techniques involved in optogenetics have made possible the manipulation of specific brain regions, allowing for an unprecedented level of control over targeted cell type, neurological events, and event timing. Previously, neither electrical stimuli nor drugs were sufficiently specific for the task.

Optogenetics stands to greatly expand the current understanding of the hippocampus, a region of the brain directly implicated in memory. Initial research into the hippocampus has investigated both the insertion and deletion of memories in laboratory mice.

In July 2013, scientists at the RIKEN-MIT Center for Neural Circuit Genetics successfully created false memories in the hippocampus using fear conditioning combined with optogenetics techniques. Researchers conducted experiments with mice that explored the relationship between external stimuli and internal representations in order to better understand the process by which humans acquire faulty memories and associations.

Per research procedure, Susumu Tonegawa and his colleagues initially placed each mouse in a safe chamber where no stimulus was administered to the subject. They then moved the mouse to a second chamber, where they administered a foot shock and stimulated a memory-forming protein in the dentate gyrus of the hippocampus—effectively forcing the mouse to recall its prior experience in the first chamber. Memories associated with pain or trauma are particularly potent, so when the mouse was returned to the safe chamber, it froze and panicked in the same way as it did in the second chamber. This means that the mouse remembered being shocked in the safe chamber – an event that never actually took place.

> “The technology we developed for this study allows us to fine-dissect and even potentially tinker with the memory process by directly controlling the brain cells.” - Susumu Tonegwa

“Compared to most studies that treat the brain as a black box while trying to access it from the outside in, this is like we are trying to study the brain from the inside out,” Xu Liu, a member of the research team, said to MITNews. “The technology we developed for this study allows us to fine-dissect and even potentially tinker with the memory process by directly controlling the brain cells.”

According to the researchers, their results particularly highlight the unreliability of memories. “My hypothesis is that, actually, this (unreliability) is a trade-off of other functions that the human brain acquired during evolution,” Tonegawa said. “Human beings are very imaginative and creative animals.”

Raising similar questions of memory reliability, Dr. Inbal Goshen of the Hebrew University of Jerusalem took the opposite approach of erasing traumatic memories in laboratory mice. Using a light-sensitive protein programmed to affect only certain brain cells, his team injected a virus with the protein into the mouse hippocampus. They then lit the mouse’s brain with an optical fiber and placed the mouse into a fear-inducing environment. The illumination of the brain deactivated the targeted cells treated with protein and therefore erased the traumatic memory in real-time, causing the mice to no longer exhibit a fear response.

Even mice that had been previously conditioned to be afraid of the experimental environment appeared to lose their traumatic memories and sense of fear. While these techniques are still too risky and invasive for human use, Goshen believes that memory modification may be the first step in the development of brain therapies for patients with schizophrenia, depression, and post-traumatic stress disorder. Echoed Tonegawa, “It’s not because we want to implant or ‘incept’ some false experience into the human mind, but because it could be useful, eventually, to develop methods to reduce cognitive abnormalities associated with psychiatric diseases, such as the delusions experienced by patients with schizophrenia.” ■

Review: Of Moths and Men

BY CAYMAN SOMERVILLE,
ENVIRONMENTAL SCIENCE, 2017

To this day, Charles Darwin's scientific findings are considered the foundation of evolutionary biology. Darwin's master work, published in 1859, was the first to propose natural selection as an instrument for the then-revolutionary theory of evolution. However, in 2002, a journalist wrote a controversial book questioning evidence supporting natural section, entitled Of Moths and Men: Intrigue, Tragedy & the Peppered Moth. In it, author Judith Hooper outlines her allegations of poor experimental practice within researcher Bernard Kettlewell's experiments on the classic example of natural selection: the peppered moth.

Teachers often use the peppered moth as evidence for natural selection. The species of moth, known as Biston betularia, has two forms: a light-colored body, known as typica, and a dark-colored body, known as carbonaria. Prior to the Industrial Revolution, typica was predominant within England. However, near the mid-1800s a dark-colored form of moths began to emerge. By the end of the century, black-colored moths were far more common – they made up 98 percent of peppered moths in Manchester, England. Scientists attributed this new form to "industrial melanism," the darkening of species in response to atmosphere pollutants from industrialization. While previously the typica moth had camouflage against the light tree bark of England, the carbonaria became masked against newly soot-covered trees. The dark moths were less preyed on by bird predators, thereby passing the carbonaria gene on at a higher frequency.

Hooper specifically criticizes the most famous experiment ever performed on the peppered moth. In the mid-1900s, Bernard Kettlewell carried out release-capture trials in the industrial and non-industrial woods and found that the dark moth fared better in the former. However, Hooper points out issues that question the credibility and validity of the results. According to The Guardian, she suggests that the "living proof of Darwin's theory of natural selection" was instead a scam, highlighting that Kettlewell's field notes had conveniently been lost. Additionally, she writes that the researcher altered the experiment to force the desired results—in effect, branding it as an inadequate example of natural selection. For example, Kettlewell placed moths onto the sides of tree trunks in his procedure, forcing their location in nature.

Despite setting out to find gaps in Kettlewell's research, Hooper dwells on details, misrepresents the state of scientific questions and fails to consider greater weaknesses, such as Kettlewell's failure to consider moth migration or thermal physiology. Though Hooper is right to investigate the outdated research, she approaches her analysis with a lack of scientific understanding and fails to recognize the difficulties in conducting natural selection research.

Photo courtesy of ian kimber, Biological Records Centre

Many experts have defended Kettlewell aggressively, attacking Hooper for developing a conspiracy theory in hope of fame. As the research is more than 50 years old, scientists could easily use more accurate methods to confirm the hypothesis. Yet, despite the criticisms for Kettlewell's research, scientists acknowledge his basic conclusions as quite correct—a testament to the solidity of original Darwinian theory, as well as of Kettlewell's own research methods. ■

Reverse Vending Machines

BY MOLLY TANKERSLEY,
ENVIRONMENTAL SCIENCE, 2016

Citizens of Beijing have discovered a new incentive to recycle, as "reverse" vending machines find their way to subway stations around the city. Exactly as the name suggests, these machines essentially do the opposite of a vending machine: Pay people who use them in exchange for empty plastic bottles. Pop the empty beverage in the hole and the machine puts it towards subway fare. It accepts PET (polyethylene terephthalate) plastic, what most single serve bottles are made of. The plastic is crushed and sorted, and in return, the machine dolls out between 5 fen and 1 jiao (about $0.50 in American money) in subway credit.

The program, known as the recycle-to-ride initiative, has come about as recycling firms look to reduce environmental impact and edge in on a potentially billion-dollar industry currently dominated by informal recycling processes. Bypassing the U.S. in 2010, China now has the largest consumption of PET bottles in the world, most of which are processed by collectors and scavengers after consumer use. This informal recycling system is so effective in its collecting that the recycling rate in China is nearly 100 percent. The problem is that no regulated laws or consequences are in place to monitor the environmental impact of recycling of plastic waste, and as a result, serious environmental issues have risen. Incom, the company that operates the reverse vending machines, hopes to raise efficiency and reduce pollution.

Despite these optimistic goals, there are those who doubt the operation's ability to succeed. Collectors and scavengers offer from 1 to 1.35 jiao per bottle, as well as door-to-door pick up services. It's possible that without the high rates on par with what informal collectors offer, consumers wouldn't have enough economic incentive to make use of the machines. However, a study on the recycling collection system of PET bottles in Beijing might suggest otherwise. The study aimed to pinpoint the most effective system Beijing could adopt through examining the systems of Japan, the U.S., and Brazil, as well as surveying PET consumers and recyclers. The survey concluded, "From the view of consumers, the most effective method to improve the system is 'arrange auto reverse vending machine for used PET bottles.'"

In terms of waste production and efficiency, the jury's still out on whether these recycle-to-ride machines will make a significant improvement to Beijing's current system. Regardless, the devices propagate the idea of recycling as not only an environmental activity, but also an economic one. Who wouldn't love the satisfaction of saving some cash and saving the world all before their morning commute? ■

Big Data is Watching

BY CLAUDIA GEIB, JOURNALISM/
ENIVRONMENTAL SCIENCE, 2015

Those who have read George Orwell's dystopian novel *Nineteen Eighty-Four* will recognize the concept of "Big Brother," a system of mass surveillance, in which every person in a society is monitored to prevent any opposition to the government. While such a system might seem to exist only in the imaginations of conspiracy theorists, recent technological advances have allowed the rise of a practice that might have made Orwell himself nervous: the collection of information called, ironically, "big data."

Concerns about big data came to a head in June, when The Washington Post and The Guardian revealed the existence of a joint big data-mining program by the National Security Agency and Federal Bureau of Investigations. The program, called PRISM, can access information on US citizens by tapping into the central servers of companies like Google, Facebook, Skype, Yahoo and Apple.

Yet a Google search for the term "big data" does not define it as an online peeping Tom, hidden behind favorite social media sites and bent on invading private lives. In its most basic form, big data describes huge sets of information gathered from various sources. This data is usually analyzed in search of patterns and relationships, often for use in improving the functionality of a company or organization.

Until recently, the sheer volume of information available through big data collection overwhelmed computer platforms. This made it impossible to take advantage of the full set of information available. New software developments and dropping prices for online storage have only recently made it possible, and beneficial, for companies to take advantage of all the information Internet users put into cyberspace every day.

For businesses, the collection of big data is a vital and growing field. Big data can allow a business to read the desires of their online customers by analyzing social media posts, Google searches, and frequently visited websites. It can allow a store to tailor a customer's coupons to suit their frequent purchases, a company to analyze its employee performance to improve efficiency, or a website to offer personalized advertisements to visitors. It is even being utilized by police departments, which analyze arrest patterns alongside holidays, rainfall, and paydays to predict "hot spots" of criminal activity and send patrols to appropriate areas.

So, big data means no more useless coupons? Not having to see weird ads on the side of Facebook? Stopping crime? What could be so bad about that?

The issue is that big data is not always limited to checking out what website you buy shoes from. Beginning in late 2012, a former NSA and CIA employee named Edward Snowden leaked information and documents to the Guardian and Washington Post revealing the existence of PRISM, a much larger and more invasive system for big data mining. The newspapers' investigations and subsequent exposés revealed that the NSA program can access several popular servers to extract photos, documents, e-mails, audio files, video chats, and connection logs from virtually anyone. PRISM focuses on foreign communications, which often move through US servers regardless of their origin, in search of individuals involved in terrorism and espionage. Yet every day PRISM also takes in communications data from ordinary Americans, a "side effect" said to be unintentional. As a result, many are concerned that PRISM poses a threat to citizens' privacy rights.

Interestingly, the government is authorized to conduct programs like PRISM by a law much older than the Internet. The Foreign Intelligence Surveillance Act, passed in 1978 and amended in 2008, allows the government to collect surveillance data as long as it is specifically monitoring "foreign powers" or "agents of foreign powers."

This law does not mean that PRISM has had an unquestioned existence. In October 2011, a secret ruling by the Foreign Intelligence Surveillance Court found PRISM to be at least partially unconstitutional. In his ruling Judge John D. Bates, chief judge of the intelligence court at the time, wrote that the NSA was not properly minimizing the collection of domestic communications in order to protect ordinary Americans' privacy, and that he was disturbed by the magnitude of the program.

"The court is troubled that the government's revelations regarding the NSA's acquisition of Internet transactions mark the third instance in less than three years in which the government has disclosed a substantial misrepresentation regarding the scope of a major collection program," Bates wrote. The court concluded that the upstream collection of Internet transactions containing multiple communications was, in some aspects, deficient under both statutory and constitutional law. However, this ruling was not made public until recently, and did little to influence the agency's activities.

Privacy advocates say that PRISM violates the First Amendment right to free speech, as well as the Fourth Amendment right against unreasonable searches and seizures. As a result, the American Civil Liberties Union and several other groups have already filed suit against the NSA and the websites involved.

Opposition to PRISM has been the rallying cry for civil liberties advocates, yet there are growing concerns about all types of big data, even at its smallest. Any big data collected from the Internet could be considered an invasion of privacy if taken without the consent of the owner. Some also worry that the government, lured by the heady rush of information, will forget that big data is not just a set of numbers, but a reflection on human beings.

In their Foreign Affairs article "The Rise of Big Data," Kenneth Cukier and Victor Mayer-Schoenberg explain how data collection often leads to suffering on the part of the people behind the data. Governments may, for example, use the data they collect to rezone communities without consideration for how the area has been structured for decades. Government agencies tend to "take all the imperfect, organic ways in which people have interacted over time and bend them to their needs, sometimes just to satisfy a desire for quantifiable order," the authors write.

The Internet now touches every aspect of life: how we communicate, how we travel, how we learn, how we shop, how we eat, how we fight and how we fall in love. By depending so greatly on the web, users place huge amounts of personal information into cyberspace, where it is easy to collect and difficult to protect.

Such large amounts of information make it a challenge to decide how data should be regulated, as well as what defines acceptable use of this data. Internet users have grown accustomed to websites knowing automatically what city they are in and for online advertisements to reflect recently visited websites. Yet where does one draw the line? What can be defined as "private" if information is place voluntarily onto the Internet? And, as government officials are fond of saying, if we have nothing to hide, what are we worried about?

PRISM has opened a new conversation about the Internet and privacy, and one that is not going away. Much like the embarrassing photos, drunk tweets, and scandalous Skype videos that the NSA has in their possession, public debate over the legality and morality of PRISM is not going to be deleted anytime soon—and as such, it will continue to shape the relationship with our most fickle friend, the Internet, well into the future. ■

RENEWABLE ENERGY: What We Can Learn from Brazil

JOHN JAMIESON, CHEMICAL ENGINEERING, 2015

Is it possible for a country to meet half of its total energy needs with renewable sources? Sure is. Look no further than Brazil, which is quickly becoming recognized as a worldwide leader in renewable energy.

Twenty-three Northeastern students traveled to Sao Paulo this summer on a Dialogue of Civilizations program which explored Brazil's fascinating renewable energy sector. The month-long trip included site visits to the recently constructed Tanquinho solar power plant, the Henry Borden hydroelectric plant, and the Sao Joao landfill, which emits methane that is captured and burned to produce electrical energy. Students were also given a tour of one of Bosch's Brazilian locations, where flex-fuel automotive engines are manufactured and tested.

Students also had the opportunity to meet Milton Flavio Lautenschlager, the Sub-Secretary of Renewable Energy of Sao Paulo. The Secretary gave an overview of Sao Paulo State's energy goals for the future, which included increasing the renewable portion of the state's total energy usage from 56 percent to 69 percent by 2020. For comparison, the United States' goal for renewable energy is to expand electricity generation from renewable sources to 25 percent by 2025.

So how does Brazil do it?

Brazil's vast network of powerful rivers has been tapped to produce close to 70 percent of Brazil's electricity. Brazil's second key energy resource is sugar cane, which can be converted to ethanol much more efficiently than corn can. Ninety percent of new cars on the road in Brazil are flex-fuel vehicles, which can run on either gasoline or ethanol.

Students took what they learned about renewable energies and incorporated it into a final project where they researched their home state's biggest energy needs and drafted a

letter to a senator describing changes that could help the state's energy profile.

The main challenge facing renewable energy is that it is currently too expensive. But if we learn from others, think creatively about the resources we have, and engineer improvements to our current alternatives, there is plenty of hope for a sustainable future. ■

Solar Boat Club: The Road To Dayton

BY CAYMAN SOMERVILLE,
ENVIRONMENTAL SCIENCE, 2017

Northeastern University's Solar Boat Club is a student-run engineering organization that constructs and designs a solar-powered boat each year. It is a small but dedicated group of about 10 members. These students use skills they have acquired through co-ops and classroom experiences to build and improve a boat that runs solely on solar panels and batteries. In 2009, a gracious Northeastern alumnus gave a gift to fund the project's launch and highlight the potential of green technology. A group of mechanical engineering students designed and built the boat from scratch, constructing the hull, drivetrain and steering mechanism themselves. Later, a capstone team of seniors added the solar panel system, propeller, electrical system and newest hull design. Since it was foudned, the project has expanded into something much more than a hobby to its members.

The club members have entered their project into two Solar Splash World Championships, in 2011 and 2013. The races consist of three parts: endurance, sprint, and slalom. This year the team took 10th overall, second in the technical report and first in visual display. This was a solid improvement from their 2011 placing (15th overall) and can be attributed to their progress in the boat's engineering design.

The Boston Family Boat Building lent the club a trailer and provided the necessary supplies, in exchange for the Solar Boat Club's involvement in their community outreach program, teaching students about engineering and electricity.

The team is constantly working on plans for improving their solar boat. They want to construct more robust yet lighter solar panels and improve their panel mounting to get around the difficulties associated with shading (such as cloud coverage). Additionally, they hope to make their electronics more efficient through power management programs, new displays, a hydrofoil, a new rudder design and a steering console. It is through these improvements that they hope to make it to this year's competition, in Dayton, Ohio, and hopefully improve their placement in each race.

Club President Christopher Hickey is a mechanical engineering major who has always found interest in transportation vehicles–whether airplanes, cars or boats. He represents the typical type of student that would take on such a project, joining the club while it was still young in order to take on responsibilities and build the club from the ground up. Not only is he gaining skills from the hands-on experience, but also building skills essential and applicable to his career.

On the other hand, it is the knowledge acquired from particular engineering classes, such as fluid mechanics or strength of materials, that contributes to the solid modeling and designing that goes into manufacturing and enhancing a solar boat. More abstractly, it forces students to consider the flexibility needed to build something with limited resources and money.

Their long-term goals involve hopefully hosting the Solar Splash competition here in Boston, increasing interest in renewable energy, and potentially making it out to European races. At the moment, they are focusing on finding sponsors and recruiting new members to get more of Northeastern's community involved. ■

Cool Co-Op: Using Ultraviolet Radiation to Prevent Airborne Infections

BY SUMAYAH RAHMAN, BIOLOGY, 2016

When my coworker led me onto the roof of the Harvard School of Public Health (HSPH), I could tell that this research assistant position was going to be a little different than my previous ones.

I followed her to a small shed-like building on the center of the roof. This was the experimental chamber where I would be performing most of the experiments.

There is a small anteroom to the chamber, where there is a biosafety cabinet and various tools. Inside the biosafety cabinet is what first appeared to be a complicated maze of pipes and tubing. But now that I've spent a few months working at Steve Rudnick's lab at HSPH, my understanding of these machines has deepened considerably.

This lab studies the effects of ultraviolet radiation. UV radiation is something that often comes to mind when thinking of the sun's harmful rays and listening to warnings about skin cancer, but UV radiation also has benefits – just as it damages the DNA of our skin cells, it also damages the DNA of undesirable bacteria. Ultraviolet radiation's sanitizing effects make it a useful tool in laboratory work to ensure that a surface is free of microorganisms before beginning an experiment, in order to prevent contamination. Radiation at shorter wavelengths (UVC radiation) is most effective at killing microorganisms. Utilizing this as an engineering intervention is known as Ultraviolet Germicidal Irradiation (UVGI).

UVGI is a useful tool in settings such as hospitals, because decontaminating surfaces and air in a room can help prevent the spread of diseases such as tuberculosis, poxviruses, and influenza. However, there is also an important safety aspect that cannot be overlooked: Rays emitted from UV fixtures can be damaging to the eyes and skin of room occupants. For this reason, upper-room UVGI, where the UV rays are confined to the top portion of the room, is of interest. Usually, louvers on the UV fixtures are used to direct the rays so that they remain in the upper-room. However, the downside to the louvers is that they prevent 96 to 99 percent of the UV radiation from leaving the fixture. But the lab here at HSPH is experimenting with a new technology that helps to direct UV rays: open-cell eggcrate panels.

In the rooftop chamber, there is a suspended ceiling of these eggcrate panels. Above the suspended ceiling, the part known as the "upper-room," there is a large ceiling fan and two fixtures that emit UVC rays. Below the suspended ceiling, the part known as the "lower-room," is a spherical ball connected to a pipe. When I am performing

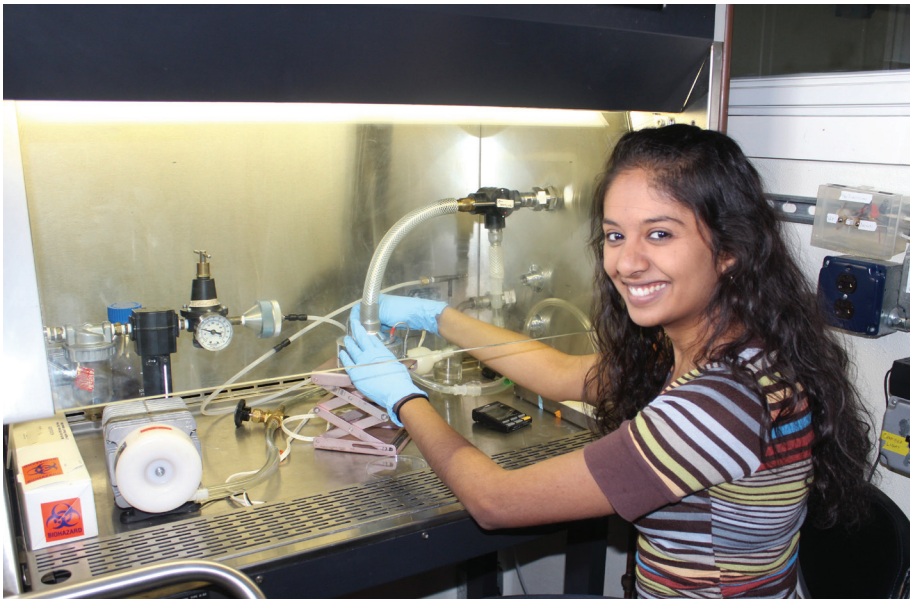


Photo courtesy of Anna Walsh, Health Science, 2017

biological experiments, I aerosolize a suspension of bacteria so that it goes through the pipe and comes out of the holes in the ball, and the aerosol particles enter the chamber. The aerosolized particles behave similarly to the particles that are released when a person coughs or sneezes and are a good representation of what may occur in a hospital room where there is an infected patient. The ceiling fan mixes the air so that the particles can reach the upper-room and be irradiated by the UV rays and then re-mixed with the air in the lower-room. The UV radiation inactivates the infectious particles, and makes the air in the room safe to breathe. The eggcrate panels are beneficial because, like the louvers, they prevent irradiance levels in the lower-room from reaching harmful levels, but they allow for maximum UV emission into the upper-room.

Here at the lab, we are trying to determine the most efficient way to utilize UVGI. In order to do this, I perform experiments in which I change different variables, including the type of eggcrate panels in the suspended ceiling, the speed and direction of the ceiling fan, the type and location of the UV fixtures and the location of the aerosol source. I typically sit in the anteroom of the chamber, where I aerosolize the bacterial suspension of either Bacillus atrophaeus (related to the bacteria that cause anthrax) or Mycobacterium parafitutom (related to the bacteria that cause tuberculosis). After allowing the bacteria to be irradiated in the chamber, I take samples using a machine called an Anderson impactor, which deposits bacteria onto an agar plate. After incubating the samples and counting the colonies on each plate, I can determine the percentage of bacteria that was inactivated by the UV radiation.

Since diseases such as tuberculosis and smallpox are more prevalent in some parts of the world than others, we are focusing on how UVGI can be applied in developing countries. This summer, Sonya Milonova, a research fellow at the lab, visited South Africa for an international conference called "Building Design and Engineering Approaches to Airborne Infection Control."

"Sometimes the problems we're working on here seem insignificant—it's easy to get bogged down by the details," Sonya said. "But when I think of the other people from all over the world collaborating with us on these problems and I see how all our results start to add up, it makes me realize I'm making an impact. We're working directly with manufacturers of new products, government officials in other countries who can change health policies, and designers who learn from us how to create environments that keep people healthy instead of spreading disease."

Sonya is an engineer, as is our supervisor Steve Rudnick. I am a biologist, as is our advisor James McDevitt. Our principal investigator is Ed Nardell, and he is a doctor. Our lab, which uses an engineering approach to solve a medical problem, is incredibly interdisciplinary, and by combining our various skills and interests, the five of us work together to make advancements in the field – and

Going "Brown"

Using Panda Poop for Power

BY KATE BARRAL, HEALTH SCIENCE , 2016

Researchers at Mississippi State University have given a wider view to what it means to reduce, reuse, and recycle. By utilizing the strong microbes within the fecal matter of giant pandas, scientists have found a new and more agriculturally resourceful option for producing biofuel.

That's right… panda poop. Giant pandas, Ya Ya and Le Le, residents at the Memphis zoo have generously donated their poop to science. Assistant professor and biochemist at Mississippi State University, Ashli Brown led the study that started over a year ago with the collection of fresh panda feces. "We have discovered microbes in panda feces might actually be a solution to the search for sustainable new sources of energy," Brown says of their findings.

Over 40 different types of bacterial microbes that inhabit the gastrointestinal tract of giant pandas have been identified. Many of these microbes are responsible for breaking down the tough cellulose and lignin found in plant materials like bamboo that make up about 99 percent of a panda's diet (according to the Smithsonian National Zoological Park).

Lignocellulose is also found in plant material like cornhusks, switch grass and wood chips: plant material that is generally discarded during the process of making biofuel. The majority of biofuel, the second most used energy source after gasoline, usually comes from precious food crops like corn and soybeans. The simple sugars from corn kernels and sugar cane ferment into bioethanol, which is most widely used as alternative fuel for vehicles. With the production of plant-based fuel booming, more concerns are arising on the issue of increased food costs or possible shortages of food. The process for manufacturing bioethanol from the waste crops containing the lignin and cellulose are possible but require advanced procedures, which cost a lot of time and money. The crops need to be pre-treated with heat, high pressure and sometimes acid: processes that must be done in a laboratory or an industrial factory.

This is where the microbes in panda poop come into play. The microbes in the gut of pandas are so efficient at breaking down the tough lignocellulose in plant material, that they are even more potent than existing enzymes found in termites that break down wood. "The time from eating to defecation is comparatively short in the panda, so their microbes have to be very efficient to get nutritional value out of the bamboo," Brown says, "and efficiency is key when it comes to biofuel production – that's why we focused on the microbes in the giant panda." Pandas have the digestive system of a carnivore but eat an almost completely vegetarian diet of bamboo stalks and leaves. Pandas have a short digestive tract and one stomach that do all the work in a relatively short period of time, while in relation cows have four stomachs that work to obtain energy from field grass.

More work still needs to be done in order for actual bioethanol to be produced using the science behind the enzymatic process of these microbes, but there is potential. Brown and her team at Mississippi State University are working with scientists at the University of Wisconsin – Madison to identify all bacterium in the digestive tract of pandas with their goal being to identify the most potent enzymes. Once scientists isolate these enzymes, yeasts can be genetically engineered to produce the same powerful enzymes on a large industrial scale so that biofuel can be commercially produced. With the help of natural digestive enzymes of the giant panda, the utilization of the tough, fibrous plant material that is usually disposed of, becomes an eco-friendly option that reduces cost, time, and precious food resources.

But what about the pandas? With about 1,600 giant pandas in the wild and another 300 in captivity, the total population of pandas in the world is at a scarce 2,000. There are 4.5 million people living in the greater Boston area. That means in just Boston alone, there's one panda bear to every 2,250 Bostonians. With the giant panda being on the endangered species list since 1990 (that's older than most college juniors) there's no doubt that it's one of the most endangered animals in the world.

All the research and work with pandas stands to help them. "It's amazing that here we have an endangered species that's almost gone from the planet, yet there's still so much we have yet to learn from it. That underscores the importance of saving endangered and threatened animals." Ashli Brown says of her research. A study like the one Brown is conducting not only gives the public insight into agricultural issues but environmental ones as well. This study is important because it not only paves the way for alternative fuel production, but also helps scientists learn more about the giant panda and the diseases that affect it; most of the diseases that occur in pandas affect their digestive tract. Brown states that from a conservation standpoint, "understanding the relationships between the microbes and the pandas, as well as how they get their energy and nutrition, is extremely important."

The latest information and updates on Brown's research were discussed at a press conference for the American Chemical Society this past September. Scientists and researchers continue to work towards a way to utilize these powerful gut enzymes, and additional pandas have now come on board to contribute to the cause. Samples of feces from pandas dwelling in the Toronto Zoo are now being added to the collection in order to be analyzed for important microbes.

With these new additions, the future of this project, as well as the future of biofuel, looks very bright. The need for fuel and energy exerts a demanding toll agriculturally and environmentally, but with the help of pandas, and the research of Brown and her team, a smarter and more resourceful way to harvest alternative energy may soon succeed. ■

Investigating the Higgs Boson: An Interview with Professor Toyoko Orimoto

BY GWEN SCHANKER, JOURNALISM, 2018

Professor Toyoko Orimoto has been a major contributor to the discovery of the Higgs boson in the field of experimental particle physics, the study of the most elementary constituents of nature. For a little more than a year, Orimoto has worked as an assistant professor in Northeastern University's Department of Physics. Sitting in her office in the Dana Research Center, the walls plastered with photos of her work and accomplishments, Orimoto explained how the discovery of the Higgs boson took place, key concepts that relate to the field of particle physics, and other big questions she is currently investigating in her research. Her research involves data analysis here in Boston and at the Large Hadron Collider (LHC) at the offices of the European Organization for Nuclear Research (CERN) just outside of Geneva, Switzerland. Orimoto is an integral member in both CERN and the Compact Muon Solenoid (CMS) experiment, which is a huge particle physics project hosted there. The CMS experiment attempts to understand not only the forces between elementary particles, but also the bigger picture: how the universe became what it is.

Orimoto and around 3,000 other collaborators share their independent research related to the CMS experiment to understand the basis of these elementary particles using the LHC. The LHC is an extremely high-energy particle detector, which takes snapshots of particle collisions, through which certain particles get converted into different types of exotic matter. Included in these particles is the Higgs boson particle, which decays into other types of particles, such as photons or muons. Through examination of particle detector snapshots, scientists like Orimoto are able to reconstruct the decay particles to determine whether something like the Higgs boson particle can be seen.

According to Orimoto, the Higgs was a top priority of the CMS research team for the past few years.

The Higgs boson particle is a key part of the standard model of particle physics, which, according to Orimoto, "encapsulates all we know about elementary particles and the relationships between them." First predicted by Peter Higgs and other theorists in the 1960s, the Higgs mechanism explains the masses of other particles in the standard model. Professor Orimoto described the Higgs as "the only way that [scientists] could introduce masses to these elementary particles … while preserving the predictive quality [of] the elegance of the standard model equation." The majority of the particles included in the standard model have been discovered and examined by physicists; however, up until last year, the Higgs boson was not among them.

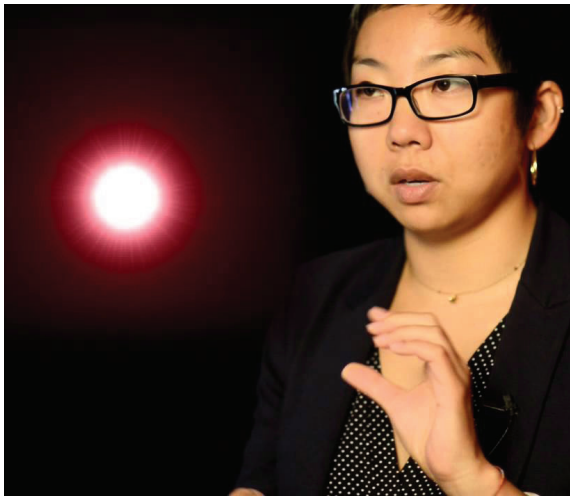
For Orimoto and her collaborators, seeing the standard model without concrete evidence of the Higgs field "was like seeing a puzzle with one piece missing," a puzzle that started to piece together last year when a particle that looked a lot like the standard model Higgs boson was discovered at the LHC. The CMS collaborators, including Orimoto, claim that what they've discovered is indeed the Higgs boson, though further tests are still being conducted to confirm its existence.

Currently, to Orimoto's excitement, the team is in a transition stage towards answering other scientific questions. When asked what areas she was most looking forward to delving into, Orimoto eagerly stated that starting in 2015, the LHC was beginning to investigate a new energy frontier. More specifically, this involves exploring the concept of dark matter, which makes up a great deal of the unknown universe but the current standard model fails to mention. Additionally, they are interested in investigating the possibility of extra spatial dimensions and the hierarchy between forces–that is, why gravity is extremely weak compared to other nuclear forces.

Overall, Orimoto said she wants to emphasize that while the Higgs boson discovery is extremely important, it is just the first achievement on a long list of goals. As CERN is still trying to confirm the discovery of the Higgs and explore other larger questions, the team is always open to students and other young people getting involved. This is possible through a couple of positions that are open every year as a co-op opportunity. The students are usually sent out to CERN during the semester.

"There's always room for smart and motivated young people to get involved," Orimoto said. "They're big contributors to the LHC experiments."

Furthermore, Orimoto wants to underline the overarching fact that scientific pursuits



ourtesy of Northeastern University, Video "Toyoko Orimoto: Searching the Next Frontier"

"There's always room for smart and motivated young people to get involved," Orimoto said. "They're big contributors to the LHC experiments."

are interesting in and of themselves. At a presentation at TedX Unige last year, Orimoto discussed her work with the Higgs boson and the idea that science parallels art: "When a poet writes a poem ... that [poem] is useful because it adds to our collective culture. Nobody asks why a poet writes poems, and I think it's similar for the science that I do ... I am intellectually stimulated, and I think that it adds to our cultural value." ■

In Vitro Fertilization: A Blessing or a Tactic?

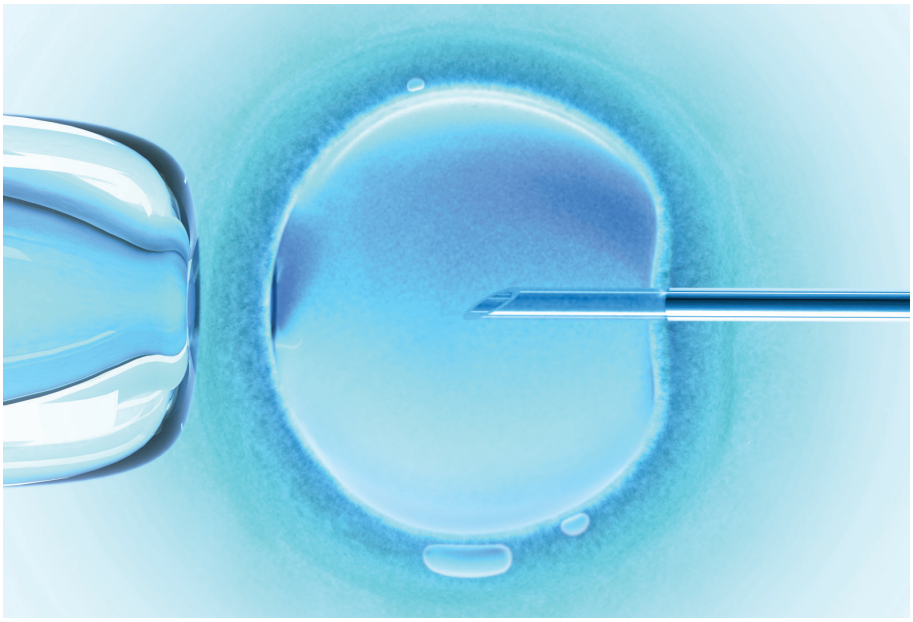
BY LEAH SIMMONS, BIOLOGY, 2016

Forty years ago, couples who were unable to conceive naturally were faced with the reality that they would never be parents to a biological child. Thirty-two years ago, in vitro fertilization (IVF) proved successful, and the first IVF baby in the United States was born. Twenty years ago, couples going through IVF paid over $10,000 a cycle; Today, couples have the option to pay a little more so that they can choose the sex of their child.

When a woman undergoes IVF, she is injected with hormones for eight to fourteen days to stimulate her ovaries. Usually, a woman produces one egg during ovulation, but these hormones cause her to produce multiple. Eggs are monitored using an ultrasound or blood testing, and when they are ready, the eggs are retrieved using a transvaginal ultrasound apparatus. The ultrasound locates the follicles in the ovary, and then the operator inserts a needle into the follicles to remove the eggs. The sperm is separated from the father's semen, and the eggs that appear to be most healthy are mixed with the sperm. The eggs and sperm are incubated for forty-eight hours, and it is hoped that a sperm will fertilize an egg during this incubation period. The embryo continues to divide for multiple days, and is placed in the woman's uterus when it is an eight-cell embryo, using a transfer catheter. The success rate for in vitro fertilization varies given the age of the woman, but it is approximately thirty percent per cycle. To date, over one million babies have been born with IVF techniques.

The key part of the process is that an egg is fertilized in a lab, and then implanted into a woman. Since the embryo has a time period between when it is fertilized to when it is implanted, there is potential for genetic selection. It is during this time that doctors and patients can observe the multiple embryos and have the option to choose one over another based on its genetic makeup.

Cases of IVF have drawn controversy to the practice. The capability to select an embryo and almost guarantee certain aesthetic characteristics has piqued people's interests. Recently, a Colorado couple using IVF hoped to complete their family by giving their son a little sister, but things didn't go according to plan. Instead, they conceived twin boys, and regretted their decision, even saying that they were dreading the birth of their twins.



It is situations such as these that stir up conversations on the morality of IVF. The couple in Colorado went into their cycle of IVF with a specific outcome in mind. However, the practice was invented in order to help infertile couples become parents, and that is how the majority of IVF patients continue to treat it. In its earlier years, IVF was so expensive that only those that could afford it and were in desperate enough situations attempted it, knowing that it was not a guarantee. It was a last effort method for couples that were struggling to conceive and still wanted a child that would be biologically their own. After years of naturally trying to become pregnant, couples saw IVF as a miracle. In cases such as these, couples are much less likely to be concerned about the aesthetics of their child, and are happy as long as it is healthy.

Prior to in vitro fertilization and other reproductive technologies, if couples still wanted to experience being a parent then they were left with the options of adoption, surrogacy, or egg or sperm donation. With IVF, infertility is still a concern, but at least there is a chance of finding a different solution. Since those trying to start a family hope for the process to be smooth and to occur naturally, it can be stressful when one is told that he or she is infertile. These stresses are relieved by the availability of other reproductive means.

There are many grey areas as to what is ethical when looking at IVF. As of now, doctors have the opportunity to screen each embryo for diseases and a few physical characteristics. In a poll, over half of people said that, if given the option, they would screen their embryos for painful diseases in order to have a healthy child. Rather than looking at it as a way to advance their child beyond others, most parents said that they would be helping their child to have a better, pain-free life. But then, that same technology is used to determine the physical characteristics and appearance of a child. Is that saving a child from harm?

There are currently no laws regulating in-vitro fertilization in the United States. It is at the doctor's discretion as to what he or she would like to offer patients. But, should there be? Or, should it be left up to the future parents? Should the government be responsible for deciding what an ethical practice is? Couples that cannot naturally have a child should not be punished because others may want to manipulate their embryos, but it does bring about a convoluted argument that may never be resolved. ■

Hearing Loss

BY JUSTINE BELINSKY, BIOLOGY, 2018

Most university students do not worry about the troubles associated with aging, such as hearing loss. However, college is the time when hearing loss can first begin, due to frequent exposure to loud concerts, gatherings and sports events. Millions of people worldwide suffer each year from noise-induced hearing loss (NIHL), including construction workers, firefighters, veterans and students. Long-term exposure to loud sounds can be harmful, but even short noises, such as gunshots, can be as detrimental to hearing as hours of sustained loud noise. Fortunately, unlike age-related hearing loss, NIHL has been shown to be at least partially preventable.

NIHL is caused by the formation of free radicals in the cochlea of the ear. Free radicals are atoms or molecules that have an unpaired electron in their outer shell, so that they attract electrons from nearby molecules, leading to cell death. Free radicals have not only been linked to hearing loss, but also aging in general.

Through experimentation on male guinea pigs, researchers identified four compounds that together prevent NIHL: Vitamin A, vitamin C, vitamin E and magnesium. They gave the control guinea pig group saline injections, while the first experimental group was given magnesium sulfate, the second experimental group was given vitamins A, C, and E, and the final experimental group was given magnesium sulfate along with vitamins A, C, and E. Scientists exposed the animal subjects to 120 decibels of sound and treated them with their respective injections one hour before testing.

After 14 days, researchers examined the animals' cochleae, counted the loss of inner and outer hair cells, and compared among the four groups. Noise-induced cell loss was much smaller in the group that received vitamins A, C and E, and magnesium in conjunction. Given the beneficial role that each of the three vitamins has in reducing free radical presence, their combination without magnesium curiously had no consistent effect on preventing NIHL in test animals. Magnesium alone, which is known to reduce noise-induced vasoconstriction, also had no consistent effect on NIHL prevention. Thus, the research suggests that only in combination will magnesium and vitamins A, C, and E significantly prevent NIHL. Additionally, the window for treatment seems to operate up to three days after noise exposure, as administration of the treatment on the third day still had beneficial effects on the animals.

Researchers have documented the potential uses of antioxidants in treating many neurodegenerative diseases, such as Alzheimer's disease, Parkinson's disease and strokes in various recent experiments. Building on that repertoire, this experiment on noise-induced hearing loss may lead to beneficial treatments for the many individuals who experience the effects of noise exposure. Perhaps a pharmaceutical agent will one day be available that anyone could take when exposed to loud noises, helping to keep their ears as healthy as they were at birth. ■

The Biology of Time

BY KEVIN O'LEARY, COMPUTER SCIENCE AND COGNITIVE PSYCHOLOGY, 2017

Humans perceive time as passing at a constant rate – and therefore would assume animals do also. A recent study from the Animal Behavior Journal about vertebrates' perception of time, however, suggests that all animals perceive the passage of time at different rates. Through years of evolution, animals have developed specific visual systems based on their ecology. In a world in which mere milliseconds can determine life or death, an animal's ability to perceive threat and information in its environment is vital to survival. However, adapting is easier said than done. There are universal constraints on adaptation, such as body size and metabolic rate. In order to determine the effects of these two variables, scientists measured how quickly different vertebrate animals perceived temporal, or visual, information.

Researchers measured how quickly animals gauged temporal information by using Critical Flicker Fusion Frequency (CFF), a process which determines the exact point at which animals perceive a flickering light as constant light. Animals with high CFF have an ability to perceive rapid changes in their visual field. The scientists' findings indicate that two main factors contribute to how quickly animals received temporal information: size and metabolic rate. Bigger animals had lower CFFs than smaller ones. In addition, animals with lower metabolism had lower CFFs than those with high metabolism.

These results indicate that smaller animals have the ability to receive more temporal information than larger animals in a given time – meaning they perceive time as passing more slowly. However, recognizing all of this information is costly in terms of energy, so temporal information is also highly contingent upon metabolism. Animals with higher temporal resolutions are more likely to survive. For instance, tiger beetles have to stop and recalibrate their path constantly when chasing prey because they intake visual information so slowly. On the other hand, in some species of flies, males are able to mate because their visual systems are so fast they can identify female flight patterns.

Human visual perception is also at the forefront of scientific study. The limits of human visual perception can be applied to numerous fields, such as the inability of baseball players to precisely track the movement and speed of a pitch and of humans to drive cars any faster than in Formula 1 racing. There is also great variation among individual visual systems in humans. The young have better systems than the old, and athletes have better visual systems than non-athletes. These findings hint that human visual systems are not entirely genetic - and that they can be changed. Andrew Jackson, a co-author of the study, said to BBC News that pushing human visual boundaries would "require either computer assistance, or enhancement of our visual system, either through drugs or ultimately implants." ■

Reef-Building Corals' Disease Response: An Interview with Dr. Steven Vollmer

BY JOSH COLLS, BIOLOGY, 2016

Dr. Steven Vollmer is a Northeastern professor who uses next-generation sequencing to study the ecology and evolution of reef-building corals. One of his favorite topics is how corals respond to disease infection. NUScience sat down with Professor Vollmer and asked him about his career and interests.

Q: Can you explain how the Three Seas Marine Biology Program uses your research?

A: A typical day for my corals class in Panama is wake up in the morning, load up the dive gear, go to the reef to identify the corals, study them and collect samples for our lab experiments, which change every year. We might take some samples for a tank experiment to look at the effects of temperature on the coral-algal symbiosis (i.e. coral bleaching) or its microbial community, or study how ocean acidification affects coral calcification by increasing the pH. The Three Seas students learn from our research, but also help us explore new questions by helping us push new research avenues.

Q: I know you are interested in coral diseases. Can you describe the particular disease you've been researching?

A: The disease is called "white band disease," which cropped up in the 80s. It infects two coral species, commonly called Staghorn and Elkhorn coral. Unfortunately, the disease epidemic swept through the Caribbean and wiped out 95 percent of these corals. That would be a loss if these were rare species, but these were the two most common shallow-water corals in the Caribbean, so it basically wiped out entire shallow-water habitats. The losses have been so severe that the United States just listed them as endangered on the Endangered Species Act. We're trying to identify what the bacterial pathogen is, and we've identified a number of bacteria that may be the pathogen. We've also identified that 5 to 10 percent of the corals are actually resistant to the disease. This should he us recover and manage these corals by propagating (i.e. farming) resistant corals and planting them back in threatened habitats.

Q: Do you use any type of genomic sequencing to determine where the disease comes from?

A: We've used genome sequencing techniques to profile the immune response of the coral infected with white band disease, but that isn't the technique to identify the pathogen. The technique we are using to identify the pathogen is microbial ribosomal gene sequencing (i.e. 16S rRNA), which is a bacterial fingerprinting tool. Basically there's a huge database for this gene, so we take coral tissue, shotgun sequence the 16S rRNA tags from the coral and then map those sequences to known bacteria in the database to help identify what the bacteria are causing the disease. It hasn't been easy because a coral can have over 10,000 bacteria it – hundreds can be associated with disease – but we can only culture maybe 100 of them. To unequivocally show that a bacteria is causing the disease we have to be able to culture and transmit it to healthy coral. That is what we spend a lot of time doing in Panama.

Q: Do you have any ideas for future research plans in attempt to narrow the search?

A: Of course. One of the angles of our research was to look at was the immune response of the coral. Corals possess innate immunity, which allows them detect virus versus bacteria versus self/non-self. Corals don't have adaptive immunity (which is found in vertebrates), which allows them to identify a particular strain of virus or a particular strain of bacteria. We started our coral immunity work by shotgun sequencing messenger RNAs (i.e. the expressed, protein-coding genes). We thought that corals would do what most animals do, which is use one of the three primary innate immune pathways: the toll-like receptor pathway, complement pathway, or phenyloxidase pathway. Our results (being published soon) show that corals don't use any of those pathways, but instead use phagocytosis and apoptosis to go around and digest the pathogenic bacteria. This finding may help us understand the coral-algal symbiosis as well.

What usually gives the coral its color are the algal symbionts that live inside the cells of the coral. Coral bleaching happens when the coral-algal symbiosis breaks down and the algae get digested or expelled by the coral. The coral algal symbioses is working the algal symbionts that live within the corals in harmony and hide themselves in the cell from being digested. We now think that the same genes that the symbiosis is built on are being compromised by pathogen infection. We now want to understand how much immunity overlaps with the coral-algal symbioses. ■

The Possibilities of Neurological Regeneration:
An Interview with Dr. Zupanc

JESSICA MCINTIRE, BEHAVIORAL NEUROSCIENCE, 2014

Many areas of medicine have advanced to incredible levels, yet the nervous system remains almost untouchable by treatment. Patients affected by brain and spinal cord injury or neurodegenerative disease have little hope of fully regaining their faculties: These are devastating lifelong conditions. But imagine if a quadriplegic man could heal so effectively that it was as if his spinal cord had never been severed. What if eight weeks after injury, he could walk, talk, and play sports again? It sounds ridiculous. It sounds impossible. It is impossible – in mammals. However, there is a type of animal that can accomplish this feat: the fish.

Dr. Günther Zupanc of the Northeastern University Department of Biology studies the regenerative abilities of fish in hopes of identifying factors that may be applicable to the development of medical treatments. NU Science had the opportunity to sit down with Zupanc to discuss his career in science, which has led to important discoveries in the field of adult neurogenesis.

Zupanc has been a part of adult neurogenesis research in fish since the founding of the field and his own career as a researcher. When he was still a graduate student, he began experiments imaging brain tissue from adult fish.

"I was very lucky that I had an advisor that allowed me to do many experiments he probably wasn't even aware of," said Zupanc. "So in addition to my thesis, I played with markers that allowed me to identify cells that were dividing."

The results were astounding: the tissue contained unprecedented numbers of dividing nerve cells. Zupanc described his surprise. "We thought 'that's an artifact,' but it was very consistent. It really turned out there's an enormous number of new cells produced in the fish brain." Experiments confirmed that fish possess ten to 100 times the number of new neurons produced in the mammalian brain.

Continued research has revealed crucial differences between fish and humans in their initial responses to injury. Injured neurons in fish undergo apoptosis, which eliminates the damaged tissue with limited inflammation. In mammals, necrotic cell death dominates at sites of injury, which results in a massive release of cytotoxic chemicals. Fish also efficiently recruit immune cells that remove potentially harmful cellular debris from sites of injury.

One of Zupanc's studies identified 24 potential proteins involved in fish adult neurogenesis. This information has enormous potential, because the same or similar proteins may be responsible for the limited neurogenesis present in mammals and could be a target for therapy.

Zupanc also found that fish retain radial glial cells in adulthood, while in most vertebrates they are present only in early development. These cells may create a chemical environment favorable for neuron growth and could also function as structural support for migrating young neurons. They may even be the precursor cells of new neurons.

These discoveries are exciting, but they do not answer a fundamental question vital to understanding the field: Why is it that fish have gained an effective system for nerve generation in adulthood through evolution, but mammals have not?

The "matching hypothesis" suggests that adult neurogenesis was present in all early vertebrates to maintain ratios of central nervous system cells to peripheral cells. When mammals diverged from other vertebrates, muscle growth shifted from hyperplasia (producing more muscle cells) to hypertrophy (enlarging existing muscle cells). Decreased production of peripheral cells meant that developing new neurons was no longer advantageous and resulted in diminished regenerative capacity of the nervous system.

It seems counterintuitive that nerve regeneration was expendable since it would be invaluable as a treatment today. But in early mammals, the inability to regenerate damaged nerve tissue would impose no additional disadvantage because serious nerve damage was rapidly fatal without the availability of prompt medical treatment. Additionally, neurodegenerative diseases, such as Alzheimer's, have an onset so late in development that it could not have been selected against during the short lifespan of early vertebrates.

Despite the progress made in the field, there is more work to be done. One obstacle is biomedical research companies' hesitation to fund labs using a comparative approach rather than the traditional method of exclusively studying mammals. Zupanc recalls the community's skeptical reception to his early research.

"There were only a dozen or so labs in the world, and we were largely ignored. People thought we were exotic people working on an exotic topic," he said. "If they had the same funding and manpower, I would expect major breakthroughs in this area."

Luckily for Northeastern students, Zupanc's passions lie not only in neurobiology, but also in education. Among his major inspirations, he includes his eighth grade science teacher who had a unique approach to education.

"He set up aquaria, brought animals to the classroom, and that was very exciting," said Zupanc. "That showed that biology was much more than learning pages 70 to 75 in a textbook."

Zupanc contributed to the development of a university with innovative curriculum strategies. In this project, initiated by astrophysicist Reimar Lüst, a diverse group of founders aimed to combine the benefits of European and American educational systems.

"On retreats, we sat together and said okay, people with different experience from different backgrounds, let's get together and assemble the perfect ideal curriculum." The result of the project, Jacobs University Bremen, is among the top biology programs in Central Europe. It is clear that just as Zupanc's scientific insight benefits adult neurogenesis research, his passion for education benefits the Northeastern community and students everywhere. ■

Would You Like a Side of GMOs With Your Burger?

EMILY ASHBOLT, BIOMEDICAL PHYSICS, 2017

Where's the beef? For Mark Post, a vascular physiologist at Maastricht University, the answer just got a whole lot more complicated.

In the beginning of August, Post, along with a team of scientists and culinary expects, cooked up a hamburger made of entirely lab-produced beef. The purpose? Cultured Beef, the name of the project, aims to find a "sustainable alternative to meat production that's more ethical and environmentally-friendly" than current meat production now.

Post unveiled his test-tube snack at tasting event held in London on Aug. 5. Chef Richard McGeown cooked the burger, mixed with breadcrumbs and other seasonings, in sunflower oil and butter and served it to Michigan Technological University nutritional scientist Hanni Rützler and Chicago food writer and journalist Josh Schonwald. The tasters were pleased with the texture of the artificial patty, but that the flavor was not quite there yet.

"We're heading for major problems in [meat production] in the coming decades," Post said to the Maastricht University Web Magazine. "So, if we can produce laboratory meat this way, only more efficiently and with a smaller carbon footprint, this could be a solution."

The theory itself is not particularly elaborate. Stem cells from muscle tissue are harvested and then placed into breeding boxes. All those boxes need are some nutrient gel and some anchor points, and then the cells, prolific by nature, do the work in a couple of weeks, spinning stands of muscle between the anchor points. Throughout their about three-month lifetime from start to burger, the cells are fed calf serum, grown medium and then, once large enough, simple nutrient sources like algae extracts. They are also "exercised" on a sugar scaffold that had its tension increased incrementally, recreating the actual usage of real muscle.

Despite the fact that this process sounds simple, it is by no means immediately implementable, for both technological and financial reasons. Currently, a Big Mac would take nearly 13,000 of these muscle strands, not to mention the in-vitro fat that also has to be grown and mixed in to create "a juicy and tasty result," according to Post. This is less Dollar Menu and more 300,000 Men, and Post has admitted that the point was more about showing that

the technology exists. It will take probably 10 to 20 years to get it to supermarkets. However, for those who struggle with the idea of killing an entire cow only to waste nearly half of it, the partial success of this attempt bodes well for the possibility of an entirely new meat market that may not be on a pasture too far away. ■

Redefining Fast Food: The Culinary Applications of 3D Printing

MATTHEW DEL MASTRO, BIOLOGY, 2017

Need a quick meal before class? While the usual college student may opt to heat instant ramen in the microwave, in the near future, he or she may be able to dig into a plate of spaghetti bolognese or roast chicken with the touch of a button. 3D printing food is on the horizon and has possible applications from the household kitchen to outer space.

3D printing refers to the process of generating three-dimensional objects from a digital blueprint. While different models may employ different methods of printing, 3D printers typically operate via robotic arms and syringe-like apparatuses. A 3D printer can produce an object from an extensive range of source materials, including compounds that emulate the trademark ingredients found in a pantry.

While neatly efficient in theory, in practice, printing with edible supplies presents some unique challenges. For instance, food is much more variable than plastics or metals. As an easily perishable substance, it has the tendency to spoil or change in consistency. As a result, today the 3D printing field manufactures foods from basic nutritional components and hydrocolloids such as xanthan gum, which provide macronutrients and texture. These simple compounds are significantly easier to store and manipulate, and can be combined to synthesize a wide variety of foods. Additional nutrients and seasonings can also be added to create diverse flavor profiles. Thus, the 3D printer can use the few building blocks of sustenance to create a many-flavored range of eclectic cuisine.

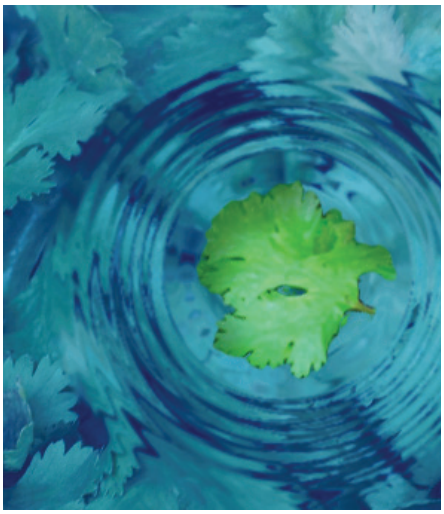
Despite the practical benefits, many consumers are wary of manufactured cubes that artificially mimic the taste and nutritional value of their favorite meals. Pioneers of digital cooking are today working with chefs and scientists alike to reconcile nutrition with a satisfying and enjoyable dining experience.

Additionally, Systems and Materials Research Corporation (SMRC) is currently collaborating with food scientists at North Carolina State University to tackle the challenge of making 3D printed food viable for consumption in outer space. Funded by NASA, they are working to create a system that can not only overcome the storage and preservation challenges of space cuisine, but also provide food that appeals to astronauts' textural and olfactory senses. SMRC believes their technology can revolutionize food not only in space, but also in countries across the globe. 3D printing presents the potential to create desirable foods from simple materials that are more sustainable than traditional crops and livestock. In a climate of rapid global population growth, SMRC believes 3D printing technology can help the world "avoid food shortage, inflation, starvation, famine and even food wars." If the world realizes the full potential of 3D printing, the concept of fast food will cease to damage world health – and instead lift it to new heights. ■

The Natural Brita

DEREK JONES, CHEMICAL ENGINEERING, 2016

Earlier this September, the American Chemical Society held its 246th National Meeting and Expo where a slew of reports unveiled new scientific discoveries and innovations. Douglas Schauer, PhD, presented a remarkable discovery he made with his team while they were working with scientists in Hidalgo, Mexico. They believe that cilantro, more commonly known for its uses in cooking, has the potential to be an excellent means to purify water for drinking and irrigation, especially in lesser-developed countries where it grows in the wild.



The outer structures of cilantro's cells appear to be optimally designed to absorb and adsorb heavy metals. These capabilities are found in the leaves and stem of the plant, making it a "biosorbent". This process has named one of the top ten natural ways to remove heavy metals from a water source by Natural News.

The commercial filters we are more accustomed to often use activated carbon to remove heavy metals from our water. While this is an efficient method of filtering water, in less developed areas such filters can be extremely costly. This new cilantro discovery enables people to go outside, grab some of the biosorbent, and know that their water is unencumbered by toxic metals. In fact, some of the experiments performed by Schauer and his team indicate that cilantro is more effective than activated carbon in eliminating lead from water.

What is the best way to make these filters work? Schauer claims one of the best ways to utilize the cilantro is to envelop it in a packet similar to a teabag. This would allow the cilantro to make contact with the liquid to be purified, but at the same time permit easy removal from the liquid. Some of his other ideas include packing it into a reusable cartridge or a tea infuser ball.

This discovery has the potential to improve millions of lives, providing clean water those who would have difficulties obtaining it otherwise. ■

NUScience Explains: Nictitating Membranes

MICHAELA RAO, BIOLOGY, 2016

Have you ever looked into a cat or dog's eye and seen something flicker across without them blinking? What you probably saw was a nictitating membrane, also known as a "haw." In cats and dogs these transparent eyelids moisturize and clear debris out of the eye. But pets aren't the only ones who have them- many other mammals, as well as some birds, reptiles, and aquatic animals do too.

The nictitating membrane aids different organisms in a variety of ways, unique to each animal. Both terrestrial and aquatic predators take advantage of the layer's transparency while stalking and attacking prey, as it allows them to blink while keeping their eyes on their intended victim. The membrane can also protect the eye when necessary. Sharks, for example, close the membrane over their eyes while attacking prey in order to protect their eyes from being damaged. On the other hand, the cleaning function is particularly crucial to animals that reside in muddy or dusty environments, such as amphibians, snakes, lizards, and low-dwelling aquatic organisms, as their vision is frequently obscured by particles that could get into their eyes. Peregrine falcons, which dive for prey at velocities as high as 200 mph, use their nictitating membranes to keep their eyes moist and clear of debris so that they can focus on their pinprick-sized targets as they plunge.

Though their functions vary, nictitating membranes are generally similar anatomically. The tissue fold, which swipes horizontally across the eye, is covered in a mucous membrane called the "conjunctiva." This surrounds a dense plate of cartilage with embedded accessory tear ducts. These ducts secrete tears which coat the eye during blinking, while the plate of cartilage serves as a protective layer that can come in handy during shark attacks – for the sharks, of course.

So if these third eyelids are so useful, why don't humans have them? Humans, along with most of their primate relatives, only have a vestige of the structure, called the "plica luminaries," the tiny flap of skin in the inner corner of the eye. It is not yet clear why humans lost the nictitating membrane during evolution – possibly because they do not hunt prey or search for vegetation for food in the same way animals that have the membranes do. Therefore, there might be no evolutionary advantage gained by a human nictitating membrane. ■

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