

NUScience

Northeastern University's First Science Magazine



Innovation in Engineering

How we're building a better world from the bottom up.

Also Inside:

- NU Engineering majors at work on their capstone creations
- An interview with Lee Makowski, Interim Chair of NU's new bioengineering department
- New materials for batteries from an unexpected source

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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 NUScience! 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,

How would the world change if we could use non-recyclable plastics to power our lives? Could we reduce energy dependency and spare our environment of another landfill? Or if we knew how to convert type A blood to type O, the universal donor? Could we save more lives, or decrease the costs of beneficial medical research? Or if we thought of cities as living and breathing things? Could we make inhabitants healthier, and find a balance with the environment?

Could we make a better world?

In this newest issue, we sit down with several Northeastern engineering capstone groups who are looking to answer these questions; and we look to other ways science and technology can better our future. We speak with the new Department of Bioengineering's Interim Chair, Lee Makowski. We explore advances in medicine, from new materials in muscle reconstruction, to fresh approaches to detecting and treating cancer; from revolutionary discoveries in stem cell research, to an app that has the potential to improve eyesight.

NUScience is also going through a time of change. This is our last issue of the 2013-2014 school year, and it's a bittersweet time as I and my fellow seniors say our goodbyes, leaving the magazine in the capable hands of our rising executive board members. I want to wish them nothing but the best. It'll be a lot of work, but it's a labor of love, and I can't wait to see what comes next.

The world is changing in front of our eyes because of innovative people coming up with ideas like blood-type converters and designs of eco-cities. But you don't need the next big idea for a better world; you just need a vision. Here's to a great future, and to the best fellow executive board members you could ask for. I'm going to miss you all.

All the best,

Jessica Melanson, Journalism, 2014

Co-Editor-in-Chief

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Check out our web-exclusive content at nusciencemag.com! Upcoming articles include:

- Newly discovered fluorescent fish create an underwater lightshow
- Why dogs align with earth's magnetic fields before pooping
- New evidence of the colorful appearance of ancient sea monsters

GOODBYE SENIORS!!

**Michael Murray****President**

First Byline: *Engineering Undergraduate Research: The Gordon-CenSISS Program, and Gliese 581G and James Webb Space Telescope, Issue 5*

Michael plans to go into software development after graduation. He eventually hopes to pursue a graduate degree in bioinformatics, a topic that first caught his attention in an NUScience article he edited. He's thrilled to have been a part of the magazine the last four years and can't wait to keep reading future issues.

**Jessica Melanson****Editor-in-Chief**

First Byline: *Doggone Shame: Herbicides Lead to Lymphoma in Dogs, Issue 5*

Jess is planning on staying in Boston, where she'll continue working in online marketing for the Boston Consulting Group. She hopes to find a full-time job in communications writing, inspired partially by her continued writing and editing for NUScience, and she's also considering law school a few years down the road. Leaving the magazine is bittersweet for her, but she's looking forward to seeing what new frontiers NUScience charges into next.

**Lauren Hitchings****Editor-in-Chief**

First Byline: *Monkey Business: Scientists Create Monkey Chimeras, Issue 10*

After graduation, Lauren will be following a science journalism or science communications track, either by entering a fellowship program or by going straight into the workforce. NUScience sparked her passion for sharing the science she loves with the world. If anyone read one of her articles over the last two and half years and at any point thought, "Wow, science is cool," then she can proudly say, "Mission accomplished."

**Emily Geller****VP of Design**

First Issue: *Issue 14*

Emily plans to stay in Boston and continue working in the art and design field. After graduation, she will embark on an art-filled trip to Europe. Once she returns to the States, she hopes to find a full-time graphic design job, and is considering graduate school for art or design in a few years. She has loved being part of NUScience and collaborating with majors of all kinds to express and illustrate concepts. She hopes the magazines will continue to include a range of majors and strengthen its identity and voice.

Interview With...

DR. TILLY

BY ELLIE SHIN, HISTORY, 2016

While no one can argue that Northeastern University boasts a strong academic program for the Department of Biology, Jonathan Tilly, new professor and Chair of the Biology Department, has visions for just how far it can go. Tilly boasts an extremely impressive resume, including multiple groundbreaking publications in the field of human fertility research and 18 years experience at Massachusetts General Hospital (MGH) and Harvard Medical School (HMS), where he served as professor, founding Director of the Vincent Center for Reproductive Biology (VCRB), and Chief of the Division of Research in the Department of Obstetrics and Gynecology. However, Tilly was ready for a new challenge, and when the opportunity presented itself in the form of the department chair position at Northeastern University, he jumped at it. When asked what attracted him to NEU, he replied, "I wanted to come back to my roots. I had spent over 18 years in a clinical environment, and I wanted to be surrounded by the energy of young minds again." He also commented on NEU's commitment to growth and improvement, and its willingness to change.

Tilly has grand plans for the Department of Biology. A major part of this plan revolves around the faculty. Tilly talked of plans to work with the Dean, Provost, and even the President to "identify and recruit some of the best minds out there" and to "identify world class leaders in research to raise the visibility of the biology program"

here at NEU. However, in choosing faculty, Tilly emphasizes that it is not just about credentials. "It's extremely important that the faculty have a commitment to students, and not just their research. A major part of being a professor at a university is mentoring and educating students, and helping to meet their needs. This could mean helping students gain experience or helping prepare them for whatever it is that they want to do in life." Tilly also commented on his commitment not only to the undergraduate program, but also the graduate program. He believes that the success of a graduate program is not determined by size, but rather the quality of experience the students receive here. He has already begun actively reaching out to candidates this year and ensuring that they will have an attractive program with well-funded labs and competitive stipends.

Tilly emphasized that having a strong faculty means nothing in the absence of an active dialogue between the students and the department. "The students here know what they want and what they need, and I think communication is essential in not only improving upon the programs offered here, but also in assessing our performance." He hopes to encourage more students to come in and initiate a conversation about what they feel the department is lacking and what needs to be improved on, whether it be the lack of certain courses that are not available, but are necessary for their desired career path, or concerns about difficulty getting into a faculty research lab.

Still, Tilly has big plans for continuing his own research here at NEU. Already an established forerunner in the field of human fertility, Tilly and his team at MGH published a paper in 2012 showing that oogonial stem cells, which they had previously identified in mouse ovaries, also existed in humans and were able to produce new viable eggs. At NEU, he plans to continue to build upon this work by confirming that this is not a mouse-specific event by working in a model system that is much closer to humans, specifically baboons. "One of our goals is to develop systems that will allow us to test the ability of baboon oocyte stem cells to produce new eggs once they are placed back into functional ovaries that can then yield offspring. If we can do this in non-human primates, it would encourage the idea that in humans it is likely to be the same case." He also plans on working to create an environment outside the body that would allow his team to take an isolated oocyte stem cell and guide it to becoming a fully functioning egg entirely ex-vivo, or, in short, create an artificial ovary. Not only would this give them a comprehensive viewpoint from which to observe its path, but would also give them a means by which to think how they could change the identity of the eggs that are produced, such as correction of single gene errors. "Our view is that instead of being reactive to disease, let's be proactively preventing it."

Tilly hopes to delve further into egg quality and how to achieve the maintenance of very high quality eggs even in older women. This would allow him and his team to first find what an egg needs in order to successfully separate its materials, including its chromosomes. It would also allow them to identify the events that are needed to make a "good egg," which would also contribute to know-how on lowering the likelihood of birth defects.

Ultimately, Tilly plans on constantly seeking what makes an oocyte tick. "One of the questions we received initially is, if these cells are there, why does menopause happen?" In researching what happens to ovaries as they get older and ultimately fail, Tilly hopes to make leaps towards delaying or preventing menopause. "We think this is a lofty and reasonable goal for one very important reason: we've already done it in mice." When it was done, the animals continued to grow old, but they did not show many of the other health problems that are often associated with age, including osteoporosis, loss of hearing, and loss of eyesight. "It tells us that ovary replacement is a viable option in thinking about health. Why not give them the opportunity for good health? Right now, women's lifespan far exceeds healthspan; our goal is to put the two events in parallel!" ■



Jonathan Tilly is eager to share his passion for higher education and reproductive health with Northeastern's faculty and students.

All You Need Is STRESS

BY MATTHEW DEL MASTRO, BIOLOGY, 2017

The best way to harness the potentially life-saving abilities of stem cells may be to drive these standard cells to the brink of death. A breakthrough study claims that exposing cells to an extreme stressor, such as an acidic environment, can induce a state of increased plasticity associated with embryonic stem cells. Since the publication of the research, considerable doubts have been cast upon the study's validity and on the very existence of the cells researchers have branded as "stimulus-triggered acquisition of pluripotency" (STAP) cells. If STAP cells are genuine, they will offer exciting insight into the process of cellular development and have the potential to finally open the door to regenerative medicine.

As an organism develops, the cells of the early embryo differentiate and become committed to various cellular fates by turning on the expression of specific genes. One embryonic cell may be converted into a neuron, while another may develop into a cardiac muscle cell. In 2006, Japanese scientist Shinya Yamanaka demonstrated the reversibility of these pathways by activating the expression of certain genes that reprogrammed adult cells into stem cells. Yamanaka's stem cells were pluripotent, meaning that they could differentiate into a variety of different tissue types. Researchers have since been eager to apply this principle of induced pluripotency to medicine. In an ideal scenario, a patient's damaged heart tissue could be replaced with healthy heart tissue grown from stem cells in the laboratory. However, imperfections in the reprogramming process have limited such clinical applications. The stem cell generation procedure pioneered by Yamanaka remains slow and labor intensive, and may even have the potential to activate cancer-producing genes along with the reprogramming genes.

In search of a more effective method, Haruko Obokata at the RIKEN Center for Developmental Biology in Japan and Charles Vacanti at Harvard Medical School turned to the kingdom of plants. They knew that extreme environmental conditions could trigger a plant cell to enter a pluripotent state. To determine whether this effect was possible in mammalian cells, the team exposed fully differentiated mouse cells to low pH conditions that were acidic enough to provide significant environmental stress while remaining sub-lethal. The cells were selected from genetically modified mice possessing a gene that caused their cells to glow upon production of the Oct-4 protein, the presence of which is unique to pluripotent cells. Within a

week of the 30 minute acid bath, researchers observed an astounding result: the cells treated with acid formed thriving colonies, each emitting a vivid green glow.

The glowing cells were suggestive of pluripotency, but the team performed a number of additional trials in order to demonstrate that the treated cells truly possessed the ability to differentiate into many cell types. The STAP cells were grafted into mice in order to induce the growth of teratomas, tumors composed of tissue types from all three known germ layers. The occurrence of teratomas suggested that the STAP cells were able to form a diverse variety of cell types. To further demonstrate the acquired pluripotency of the cells, researchers produced chimeric mice by injecting the STAP cells into early mouse embryos. The chimeras, mice composed of cells from multiple genetically distinct populations, incorporated the STAP cells into every tissue type that the researchers inspected. Furthermore, the chimeras produced viable offspring containing STAP cells, demonstrating that the cells could be inherited and could produce normal offspring.

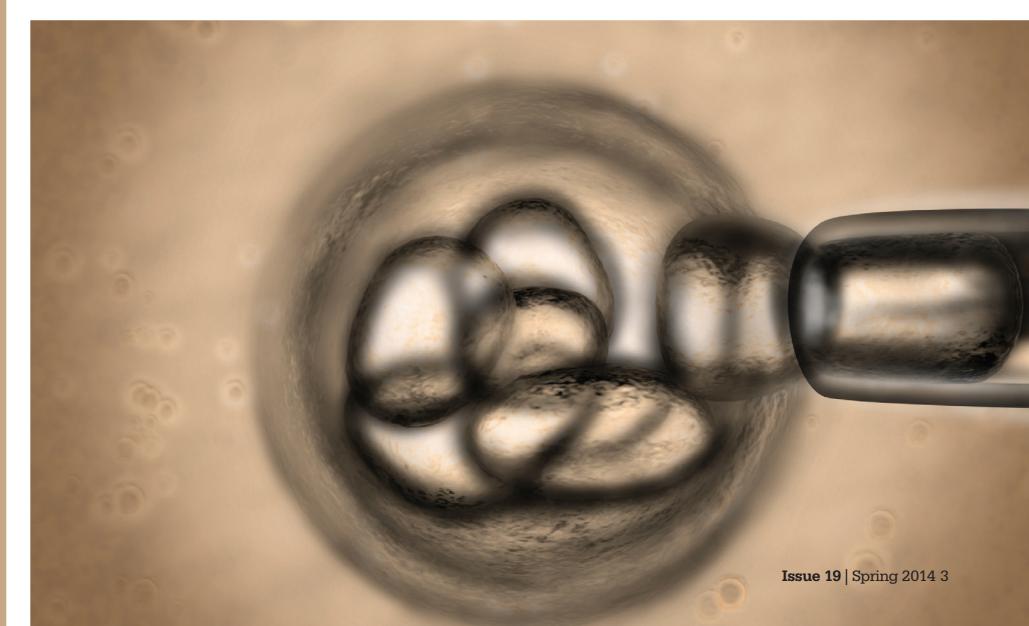
The STAP cell revelation raises a number of new questions about cellular development and gene regulation. Why should shocking cells to the point of near death cause them to enter the pluripotent state typically associated with the early embryo? One possibility is that the acquisition of pluripotency is part of a natural injury repair mechanism, allowing cells to alter gene expression in order to adapt to extreme damage and then differentiate back into normal cells to repair the injury. Yet there remains the puzzling question of why increased pluripotency

Acid Bath Induces Reprogramming into Stem Cells

is not seen in cells subjected to drastic damage in living organisms. Investigating the questions put forward by the discovery of STAP cells may unveil new insights about the inner workings of the cell.

STAP cells, if they are real, may also have immense applications in the clinical setting. The cells treated with acid became pluripotent in only a week, while stem cells produced using the traditional gene insertion method can take up to a month to reach this state. Vacanti is hopeful that his simple and cost-effective method can finally make regenerative medicine a reality. He told *New Scientist*, "We can use the technology that we have demonstrated today and come up with ways to perfuse tissues with healthy cells. That way we can boost function and transform it from a failing organ to an organ which will survive."

Despite this optimism, researchers in the stem cell community are not finding the technique to be as simple as it initially seemed. Not one of the ten stem cell experts contacted by *Nature* in the weeks following the publication of the Obokata and Vacanti's paper have been able to successfully replicate the results. Additional skepticism has been directed toward the study after the uncovering of discrepancies in the paper's results, which include duplicated images and graphs that were spliced together. These findings led Teruhiko Wakayama, a co-author on the publication, to admit to NHK News that he had "lost faith in the paper." Future research will determine whether STAP cells will become the medicine of the future or a forgotten relic of the past. ■



New Discoveries Through NuSTAR

BY EMILY ASHBOLT, BIOMEDICAL PHYSICS, 2017

Supernovae are catastrophic and dramatic intergalactic events that have the potential to reshape the entire solar system. It is from these events that we get the heavy elements that make up the cosmos themselves. They also have the potential to send shockwaves through the galaxy that can spread for light years. Until very recently, scientists had very few ideas of how supernovae originate, and little way of knowing how correct their existing theories were.

Enter Brian Grefenstette, a professor at California Institute of Technology. With the help of his team, Grefenstette recently published a groundbreaking paper unlocking some of space's best-kept secrets through a new NASA creation called the Nuclear Spectroscopic Telescope Array, or NuSTAR. NuSTAR is a collection of X-ray telescopes that can see the kind of high-energy x-rays created by massive cosmic events such as supernovae.

Created in 2012, NuSTAR has recently been pointing at Cassiopeia A, a type Ib supernovae

in the constellation Cassiopeia, about 11,000 light years away. This vast distance means the light from this supernova first reached Earth in the 1660s. Normal deep-space telescopes can see the remains of the massive explosion that turned Cassiopeia A from a suspected giant star approximately twenty times the size of our sun into the supernova we know it as today: a smear of debris that, when viewed from Earth, spans across ten light years. However, what makes NuSTAR useful is that it can constantly see the radioactive material present in the remnants of such an explosion. Previously, this nuclear material could only be seen when heated up.

Grefenstette is hopeful about this advancement. "With NuSTAR we have a new forensic tool to investigate the explosion," he explained. "Now that we can see the radioactive material...we are getting a more complete picture of what was going on at core of the explosion." Knowing what happens at the core of a supernova could help unpick the mystery

of what exactly causes such massive collapses, and how the stars react before the bang.

"Stars are spherical balls of gas, and so you might think that when they end their lives and explode, that explosion would look like a uniform ball expanding out with great power," said Fiona Harrison, the principal investigator of NuSTAR. "Our new results show how the explosion's heart, or engine, is distorted."

Specifically, NuSTAR was able to identify the decay of titanium-44 into calcium-44, a nuclear transition that occurred within Cassiopeia A before its collapse. The jet trajectory of this decay suggests that the core of the star was in motion before its collapse, gaining momentum to explode from within.

Paul Hertz, director of NASA's astrophysics division in Washington, could not be more pleased with such results, even as they throw much preconceived notion into flux. "This is why we built NuSTAR," he commented. "To discover things we never knew—and did not expect—about the high-energy universe." ■

Supermassive Black Hole Gets Ready For a Large Snack

BY DAVID ADAMS, CHEMICAL ENGINEERING, 2017

Approximately 26,000 years ago, a cloud of ionized gases and dust encompassing a volume larger than the solar system approached the center of the Milky Way. Awaiting that cloud was a supermassive black hole with a mass 4.6 million times greater than the sun. Light and radiation from this interstellar event is just now reaching Earth. Scientists around the globe are setting up equipment to monitor the results of the super-sized meet up. The provided data could shed new information on black holes: one of the universe's greatest mysteries.

Speculation over what could take place next has narrowed to a few possible courses. The

first is that the gas cloud, named G2, will begin a deadly descent directly into the black hole's event horizon, an area where no matter or light can ever escape.

Some scientists hypothesize, however, that G2 may survive the encounter. Depending on its approach, the dust and gases contained within the cloud might be bent around and away from the black hole. G2 would likely not resemble its current oval form after such an encounter. Already, infrared imagery of the cloud shows that it is beginning to stretch out and deform, with a large tendril of gas curling in the direction of the black hole's center. As the leading edge

of G2 approaches, this acceleration could shear the entire cloud into thin stretches which would fall towards the black hole in a phenomenon astronomers scientifically refer to as "spaghettification."

As the mass of other celestial objects becomes adsorbed over time, the volume directly surrounding the event horizon can become saturated with orbiting material in an "accretion disk." As G2 gets closer to the black hole it will likely come into contact with that material, providing another unknown variable in the prediction models. It is possible that the interaction could create huge forces, heating up the cloud to over 10 million degrees Kelvin, as a result of friction. Along with the increase in temperature, the center of the galaxy may suddenly light up in a cosmic rain of energetic radiation.

The results of this event are ultimately dependent on the composition of G2 and the speed and direction from which it approaches the black hole. Even with the most sensitive of instruments, this information is hard to quantify from 26,000 light years away. Once astronomers are actually able to observe the impending event, the truth will come out and any false hypotheses will be left in the dust. ■



Photo courtesy of NASA

Engineering Batteries from Viruses

BY LAUREN HITCHINGS, BIOLOGY, 2014

After years of engineering batteries that are stronger, more efficient, rechargeable for more cycles, and longer-lasting, the time has finally come for engineers to face the challenge of developing batteries that are greener. Biological engineer Angela Belcher of MIT is taking a unique approach to environmentally-friendly batteries by attempting to manufacture materials for batteries from viruses.

A typical battery contains two electrodes, a separator to keep them apart, and an electrolyte substance through which charged ions flow. When the positively charged ions move from the anode to the cathode during cell discharge, an electric current is produced. Currently, the electrodes of traditional batteries contain chemicals like cadmium and lead that are too toxic to dispose of, and most rechargeable batteries require highly reactive compounds to manufacture. The hunt for sustainable technology is on, and in an interview with *New Scientist*, Belcher said, "not just any material will do: we need ones that are more abundant and more environmentally friendly."

Viruses have a bad reputation because a few of them can be very harmful, but in reality, viruses are everywhere, and most of are completely harmless to humans. The viruses that Belcher is looking at only infect bacteria and do not kill their hosts; they simply utilize the host's molecular machinery to replicate themselves.

For researchers like Belcher and her team, viruses are ideal agents to study because their genomes are small and pliable. By simple manipulations to the genetic code, viruses can be made to produce assorted proteins that can bind to different materials. They can even create viruses with varying properties on different parts of a single protein coat, so that the proteins on a single coat can bind to different materials simultaneously. Belcher saw this innovation as an opportunity to use viruses to assemble complex protein structures that could potentially be applied in engineering.

Belcher set out in search of a way to manipulate viruses to produce particular structured proteins for sustainable materials to be used in the electrodes of batteries. In initial experiments, Belcher and her team used a long, tubular-shaped virus called the M13 bacteriophage to first test if it would even be possible to use a virus to grow materials for electrodes. She and her team inserted a gene that caused the virus to produce a protein coat that binds with compounds such as cobalt oxides and iron phosphates to grow nanowires, which were then successfully used in an electrode for a prototype bio-battery.

Once they had established proof of principle, the team began working on optimizing the

performance and capabilities of the electrodes made from phosphate nanowires. In order to do this, they needed to find which virus would be best to produce proteins that would favorably bind to conductive carbon nanotubes (CNTs). The team tested nearly a billion different viruses and forced them to interact chemically with the carbon nanotubes by mixing them in a test tube. After analyzing the results, they selected the thousand or so viruses that had successfully attached to the nanotubes and cultured more of them by allowing them to infect bacterial hosts and replicate. With more copies of each of the viruses on hand, the researchers again forced the candidates to interact with CNTs and narrowed their options down to only those virus candidates that bonded best to the CNTs.

After many rounds of this "survival of the fittest" testing, Belcher found a single virus that was best able to coax iron phosphate nanowires to grow into a particular shape as well as serve as glue to bond those nanowires to the CNTs, resulting in a conductive composite. Once the composite was completely developed and dry, it was incorporated into a battery to test whether it was functional. The final product looked and worked the same as an ordinary, functional battery, but one or both electrodes inside were grown with biological material.

As it turns out, the biologically produced nanowires were more than just functional. Unlike traditional, chemically-produced nanowires, which are smooth, the biological nanowires have a spiky surface with more surface area. This allows more room for electrochemical activity to occur when a battery is being charged or used, and thus its charge-storage capacity is better

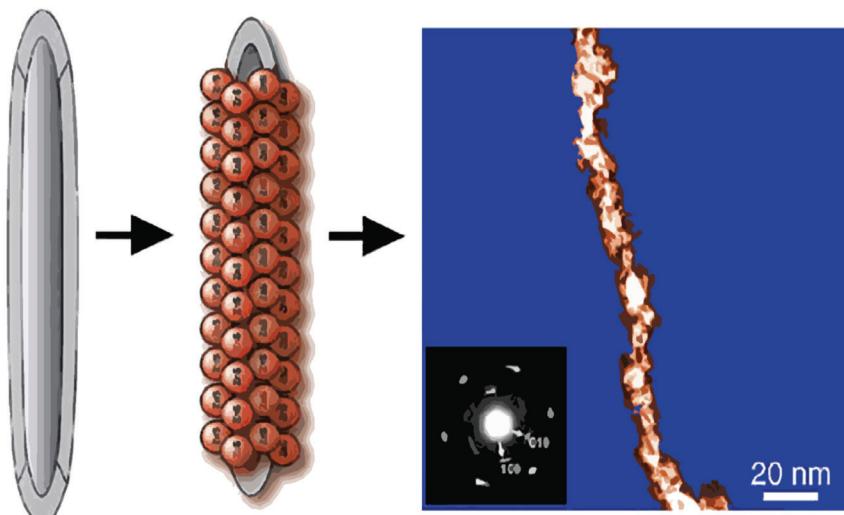
than the standard.

This technology has opened the door for Belcher and her team to explore the potential of creating environmentally-friendly lithium-air batteries, which are powered by reactions with oxygen that are inefficient on normal, smooth nanowires.

While bio-batteries are promising, they are still experimental. They have demonstrated impressive performances in small devices such as flashlights, laser pointers, and watches, but they don't yet have the lifetimes to compete with the traditional batteries that are currently on the market. The team hopes to develop their research further and eventually produce small bio-batteries that can beat current standards, but first they will need to drastically improve power performance.

Further down the line, the team also hopes to be able to grow large bio-batteries for devices like cars and computers, which require significant energy and long usage time. Another goal in sustainability is to make the bio-batteries rechargeable for thousands of cycles; so far, they have been able to produce batteries that are only rechargeable for hundreds. Finally, the team's ultimate goal is to make all of these batteries completely biodegradable. Bio-batteries are already greener than most commercial options because the materials used to make the electrodes are benign to the environment, unlike the typical toxic cadmium and lead. In an MIT press release, Evelyn Hu, co-founder of Belcher's two companies, stated, "[Belcher's] inventions are always linked back to her profound passion and compassion for society, and her desire to improve the quality of life for others." ■

Photo courtesy of Nature Biotechnology



Unraveling the Mammogram

BY HEESU KIM, PHARMACY, CLASS OF 2018

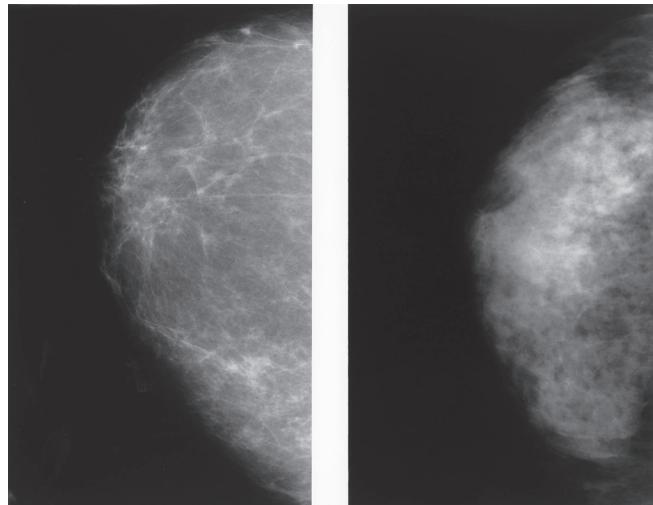
Challenging the practice of annual breast screening, a 2014 study has submitted new evidence that mammograms fail to decrease the breast cancer mortality rate of females aged 40-59. The findings contradict existing standards for screening as set by healthcare giants; currently, the American Cancer Society advises annual mammogram testing from age 40. The U.S. Preventive Services Task Force recommends biennial testing from age 50.

The recent study represents the 25-year follow-up of the massive 1980 Canadian National Breast Screening Study (CNBSS), which evaluated mammography and physical breast exam benefits in 89,835 women between 40 and 59 years of age. The CNBSS sorted the subjects into age groups of 40-49 and 50-59 years, in which half were blindly assigned to receive mammography screening and half to no mammography. Annual physical breast exams were administered to women in the mammography arm of the 40-49 year age group, as well as all women in the 50-59 year age group.

During the five-year screening period of the 1980 study, 666 incidents of breast cancer were diagnosed in the mammography arm, while 524 breast cancers were diagnosed in the control arm. The 25-year follow-up period yielded diagnoses of 2,584 more breast cancers in the mammography arm and 2,609 more breast cancers in the control arm. By the completion of the 25-year follow-up period, a total of 1,005 women—500 from the mammography arm versus 505 from the controlled arm—had died of breast cancer. The final analysis found that death rates were identical for women who received mammograms versus those who did not.

The CNBSS concluded that in conditions of freely available breast cancer therapy, "annual mammography in women aged 40-59 does not reduce mortality from breast cancer beyond that of physical examination or usual care." In an additional challenge to the mammogram, the CNBSS revealed that 22% of breast cancers found through mammography were over-diagnosed, representing one over-diagnosed breast cancer for every 424 screened women. Hence, the study suggested that women receiving annual screening have more breast cancer diagnoses, but the same rate of mortality as unscreened women. The study did not speak to the use of mammography as a diagnostic device, where it is generally accepted as a useful and important tool.

The provocative CNBSS findings have polarized commentary from both mammography



Two normal mammograms showing the difference between a dense & a fatty breast.
Photo courtesy of National Cancer Institute

skeptics and supporters. In defense of screenings, major mammogram advocates have contested the integrity of the findings. Representing the American physicians who administer and interpret mammograms, the American College of Radiology (ACR) released a critical statement suggesting that researchers used faulty practices during trials.

"The recent breast cancer screening article... published in the *British Medical Journal* (BMJ) is an incredibly misleading analysis based on the deeply flawed and widely discredited Canadian National Breast Screening Study (CNBSS)," the ACR stated in a written press release. "The results of this BMJ study, and others resulting from the CNBSS trial, should not be used to create breast cancer screening policy as this would place a great many women at increased risk of dying unnecessarily from breast cancer."

“By the completion of the 25-year follow-up period, a total of 1,005 women—500 from the mammography arm versus 505 from the controlled arm—had died of breast cancer.”

The ACR cited the use of outdated equipment and poorly trained technologists and radiologists as contributing factors to the unfavorable CNBSS findings. Controversially, the ACR also suggested that CNBSS researchers used a stacked system, in which women who were more likely to die from large incurable breast cancers were deliberately assigned to the mammography arm of trials.

Yet, a 1997 review of the CNBSS was conducted when similar doubts were raised about the original study, and found no evidence of foul play in the research design. Criticizing the ACR for leveling old allegations at a new study, Dartmouth medical professor H. Gilbert Welch has suggested that diehard advocates are impeding

important developments to mammography screening science.

"To be clear, not all mammographers share this view," Welch wrote. "A new generation has openly acknowledged the problems of mammography. But many in the old guard are more likely to attack any suggestion that screening doesn't work as well as advertised, characterizing researchers who raise the possibility as 'malicious' or 'dangerous' and questioning the editorial policies of the journals that publish their work. It's time to stop the unfounded allegations. It might be standard procedure for politics but not for science. Too much energy has been devoted to discrediting the Canadian study and not enough to understanding it."

Indeed, the current body of mammography research is murky. The CNBSS authors affirmed that their findings contradict older established studies, including a 29-year Swedish study which concluded that screening reduced breast cancer mortality by 30 percent. They also stated that mammograms were an important tool for women with naturally lumpy breasts.

As long as science does not fully understand the efficacy of mammography, Marissa Weiss, founder of breastcancer.org, has suggested the importance of vigilant screening.

"What we're talking about is the most common cancer to affect women and something that is treatable with early detection," Weiss said. "It makes sense to do what you can that's reasonable to try to find it as early as possible so that you can live as long as possible and so that you can also avoid some of the more aggressive forms of treatment, like chemotherapy."

Ultimately, progressive steps must be taken by both advocates and skeptics to achieve progress in the field of mammography. More research must be done to develop the currently ambiguous body of evidence for or against mammography screening. Mammogram advocacy groups must not allow professional self-interest to hinder the improvement and evolution of modern breast cancer care. Transparency of both sides is essential. Through cooperation and collaboration, an era of brighter, better breast cancer screening is nigh. ■

Fishing For Cancer

BY POOJA NAGARAJAN, GRADUATE STUDENT, DRUG REGULATORY AFFAIRS, CLASS OF 2015

In another of the numerous attempts to ward off deadly, malignant cancers, doctors have uncovered a new technology that entices tumor-spreading cancer cells to their final fate. This technology makes use of a tiny "fishing rod" consisting of a nanopolymer fiber, a few millimeters in length, containing a cytotoxic drug at its tip that acts as "bait" for cancerous cells.

In one of the most fatal types of cancer, glioblastoma (GBM), or brain cancer, malignant tumor cells migrate to other parts of brain via the blood vessels and nerve fibers. It is taxing to surgically access these tumors and, within a short span of time, the tumors spread to other parts of the brain, making it incurable. In an attempt to mimic these carriers, the fibers in the device are designed to behave as any normal nerve fiber and deceive these cells. When they

attach to the fiber, the cells are destroyed by the cytotoxic drug cyclopamine, which is lethal to cancer cells.

This cutting-edge technology originates from the Biomedical Engineering Department of Georgia Tech and Emory University, where researchers made use of fibers made from polycaprolactone (PCL) polymer flanked by a polyurethane carrier. This polymer is specially designed to simulate the delineations of nerve fiber, which cancer cells usually take advantage of. Research in rat and mice models demonstrated shrinkage of GBM tumors by up to almost 90 percent. "We have designed a polymer thin film nanofiber that mimics the structure of nerves and blood vessels that brain tumor cells normally use to invade other parts of the brain," said Ravi Bellamkonda, lead

investigator and chair of the Wallace H. Coulter Department of Biomedical Engineering at Georgia Tech and Emory University. "The cancer cells normally latch onto these natural structures and ride them like a monorail to other parts of the brain. By providing an attractive alternative fiber, we can efficiently move the tumors along a different path to a destination that we choose."

This technology might not completely eradicate cancer, but it is believed that it might be a step towards progressive-free cancer, meaning the cancer is not metastasizing, providing a breather to millions of cancer-afflicted patients. ■

Can You Hear Me Now?

New Drug Restores Hearing By Regeneration Of Lost Cells

BY NATASHA MATHUR, BEHAVIORAL NEUROSCIENCE, CLASS OF 2017

Hair cells, one of the smallest cell types in the body, are extremely important in the auditory system. These sensory receptors perform the critical role of transducing mechanical sound waves from the environment into electrical nerve signals understood by the brain. If hair cells move one way, the cells become hyperpolarized. This means that the cells become more negatively charged and are not excited, meaning that no action potential occurs and sound is not heard. However, if the hair cells move the other way, the cells are depolarized, or excited, which causes the release of neurotransmitters that ultimately result in a sound being heard.

Hair cells are located in the cochlea, which is connected to the auditory part of the brain. Hearing loss often occurs when there are not enough hair cells in the cochlea, which can be caused by various environmental factors as well as aging. Hearing loss can affect an individual's social and cognitive development, especially if it develops at a young age.

A recent study showed that hair cells could be regenerated in deaf mice. When exposed to a certain drug, the stem cells in the mouse's ears were coaxed to develop into hair cells. Researchers believe that the drug works by inhibiting an enzyme involved in the ear cell development pathway. They identified a specific protein that is found on the supporting cells around hair cells in the cochlea, and discovered that by preventing this protein from

being made, the stem cells in the cochlea would develop into hair cells.

This finding was revolutionary because mammals, unlike birds and fish, are typically thought to be unable to regenerate hair cells during their adult lives. When the mice took the drug, new hair cells were generated in the cochlea. This improved their hearing abilities, which was a huge breakthrough for the research group.

There had been previous hair cell regeneration studies done on birds and fish, but no studies had been performed on mammals until now. Mice have very similar systems to humans, especially in the brain, so these findings could translate to human hair cell regeneration.

Albert Edge, one of the researchers who worked on the drug at the Harvard Medical School and Massachusetts Eye and Ear Infirmary, believes that the drug will be able to pass through clinical trials in the next few years. This drug will have a significant impact on patients who suffer from hearing loss because it may be able to restore their hearing.

Many of us do not realize what it is like to be unable to hear anything in world full of sound, and this drug would really benefit those who are currently living in a silent world.

Although the drug will not be released for some time, several issues have already been raised. Researchers are unsure whether the drug will translate from mice to humans, and all regeneration projects are extremely controversial due to their use of stem cells. Stem cell research raises ethical questions because stem cells are often obtained from embryos. The study, however, offers promising proof that mammalian hair cells can be regenerated, which also opens the door for other drugs to be created and tested. If a drug can be used to regenerate even half number of the hair cells that someone with normal hearing has, it could still significantly improve someone's life. ■



Google Earth: Look for More than Just Your House from Space

BY KATIE HUDSON, MARINE BIOLOGY, 2017

Google Earth is most famous for directions, 3D images of mountains, and pictures taken from space. Now, Google Earth will partner with other businesses and nonprofits to monitor deforestation in real time.

By partnering with the World Resources Institute, the University of Maryland, Nestlé, Unilever, and a variety of other small organizations, Google Earth has become a pivotal member of the team developing the Global Forest Watch system. This system allows the public to track deforestation data from around the world. The data is updated monthly and is so accurate that viewers can see as small as 100-acre increments removed at a time.

By making this program free online, Google hopes that this new technology will educate the public about deforestation. In addition, with the Global Forest Watch program, Google is making it possible for the public to not only view this data for free, but to analyze it as well. Due to a lack of open, public resources, this has been difficult for the public to do. With this system available to them, the goal is to allow people to draw their own

conclusions about deforestation in order to get a full understanding of the situation at hand. Google is also allowing its users to make their own maps of the forest that they observe; that will help them understand "where, when, and why forests are disappearing," according to Google Maps's blog.

Deforestation is one of the major contributors to global climate change, since forests are the greatest sequesters of carbon dioxide. Researchers estimate that since the turn of the century, the planet has lost over half a billion acres of forest. This is equal to losing 50 soccer fields every minute over this time period. These forests have been lost as a result of human expansion. Forests are cut down for new land development projects, like housing, or lumber industries. In the Amazon rainforest, thousands of acres of land are lost daily to agriculture expansion and unsustainable agriculture techniques practiced across the planet.

This practice, known as "intensive forestry," is designed to make a quick profit for companies, especially in the lumber industry. Intensive forestry often involves cycling through plots of land that are planted and harvested in five-year cycles.

While these practices are vital to local and national economies, including those in the southeastern United States, the developers of the Global Forest Watch system and Google are looking to companies to move towards a "multiple ecosystem services strategy" for these industries. The data currently present in the Global Forest Watch system suggests that these strategies are more sustainable and would provide more benefits to the local ecosystems, including increased water filtration and biodiversity, while still providing a profit to companies in industries that are currently tied to deforestation. With these strategies, the data also suggests that more carbon could be sequestered, decreasing the amount of carbon dioxide released into the atmosphere by several gigatons, and, as a result, significantly slowing the rate of climate change. ■

Study Confirms Temperature as Primary Factor in Peruvian Glacier's Fluctuations

BY GWENDOLYN SCHANKER, JOURNALISM, 2018

The melting of glacial ice has been recognized for years as a signal of global climate change. Along with frequent droughts, unpredictable storms, and various other factors, shrinking glacial ice serves as one of the key signs that human greenhouse gas emissions are having a detrimental impact on natural climate patterns. While it has previously been confirmed that temperature is the main contributor to the growth and retreat of glaciers in middle-to-high latitudes, the question of why glaciers are retreating in the tropics – or why tropical glaciers even exist at all – has been a subject of controversy for years.

A recent study conducted by a research team led by Meredith Kelly, assistant professor of Earth sciences at Dartmouth University, has verified the likelihood that temperature is the main factor driving the growth and recession of tropical glaciers, rather than other imputed factors, such as reduced snowfall. The study, published in the journal *Geology*, refers specifically to the Qori Kalis glacier, part of the Quelccaya Ice Cap in Peru. Quelccaya is the largest ice cap in the tropics, and sits 18,000

feet above sea level in the Peruvian Andes.

The researchers documented Qori Kalis' movements through field mapping techniques combined with beryllium-10 surface exposure, and demonstrated that temperature is the primary factor driving fluctuations. Secondary factors include precipitation, humidity, and solar irradiance, the variability of radiant energy per unit area. Kelly and her team also took into account information from cylindrical ice cores, which have been used by Ohio State University Professor Lonnie Thompson since 1960 to date Qori Kalis' size changes over the past 500 years.

Thompson's research demonstrated that the glacier grew to maximum size during the late Holocene, more than 500 years ago, and has been shrinking ever since with few additional advances. Thompson's research also shows that the speed of ice shrinkage has accelerated in recent decades; part of the Qori Kalis glacier that took nearly 1600 years to grow has melted in the past 25 years.

By demonstrating that this rapid warming of ice is mainly due to temperature, Kelly's recent

findings make it clear that human emissions are throwing the natural world off kilter. An article in the New York Times even likened the Qori Kalis glacier to "a huge thermometer."

Kelly's team's research provides the first glacial movement record that can be directly compared to annual ice core records like Thompson's. Similar findings have already been demonstrated in other locations like the Southern tropical Andes. However, the study is not without flaws. The information reported by Kelly depends largely on Thompson's ice accumulation documentation, which has been compressed over time and so requires scrutiny. The study also warrants more research regarding how to move forward in the age of global climate change – namely, how to prevent global warming from escalating even further than it already has. ■

Into the Muddy Life of an Environmental Scientist

BY CAYMAN SOMERVILLE, ENVIRONMENTAL SCIENCE, 2017

As an aspiring environmental scientist, my journey towards a professional career has been distinctively uncharted and unorthodox. Diving headfirst into my first co-op, I felt as if one day I was unsure of which department I belonged to at Northeastern University and the next, I was on my way to the United Kingdom to pursue a newfound dream of being an environmental scientist. I saw an opportunity to co-op abroad and I refused to let it slip away from me. Driven by a passion to see the world and contribute to its preservation, I accepted an internship as a research associate on a macronutrient project at the Center for Ecology and Hydrology (CEH) in Lancaster, England.

The northern town of Lancaster holds the prominent research institute which I joined as the youngest member of its staff. Based within the campus of Lancaster University lies one of CEH's four research sites. All four sites, stationed throughout England, Scotland and Wales, collaborate and work closely together on various projects related to land and freshwater ecosystems and their interconnection with Earth's atmosphere. The center undertakes environmental problems related to the impact of global climate change, water issues, chemical, biological and physical processes in natural environments, sustainable usage of natural resources, and the effect of human activity on Earth's systems. CEH provides cross-cutting and holistic solutions to these complex challenges and works closely with the scientific community, policy makers, and the private sector. It is an integral part of the Natural Environment Research Council (NERC), the UK's central governmental agency for "funding and managing research, training and knowledge exchange in the environmental sciences." With a focus on long-term environmental monitoring and the delivery of innovative and interdisciplinary science, the research center is essential for both NERC and the UK's strategic environmental vision.

My role at the Lancaster research site was to work on a biogeochemical project in nutrient enrichment for Professor Edward Tipping, a well-respected and accomplished senior scientist. The project is referred to as the "Long-Term / Large-Scale interactions of Carbon, Nitrogen and Phosphorus in UK land, freshwater and

atmosphere," or LTLS, and aims to supply scientific knowledge on the variance in nutrient levels over the last 200 years. This project began in October 2012, and it is expected to finish by late 2015.

The balance between essential nutrients in terrestrial ecosystems has become the main focus of macronutrient cycling research and global climate change ecology. Carbon sequestration in ecosystems is driven by the supply of other essential nutrients, such as nitrogen and phosphorus. As a result of rapid population growth and consequent agricultural advancements, the global terrestrial cycling of nitrogen and phosphorus have more than doubled. When the world's natural nutrient cycles are out of balance, we face significant environmental, health and economic problems. The LTLS project hopes to address these problems through the analysis of data collected on the nutrient levels in soils and rivers throughout the UK. It also aims to understand processes that cause the acidification and loss of biodiversity within surface waters, in order to improve sustainability of agriculture, control eutrophication, decrease greenhouse gas emissions, and reduce nutrient delivery to the sea. Consequently, the investigation can provide a better scientific understanding of the interlinked carbon, nitrogen and phosphorus cycles, which can be used to develop management strategies and establish policy.

From my first day at CEH, I was fully immersed in the tasks I would contribute to throughout my internship. My co-worker was eager for me to help manage the workload and encouraged me to carry out all of the laboratory work independently. Within my first hour, she taught me the procedures behind the analysis of the river samples. Later, she acquainted me with our second laboratory and divulged the processes driving the bulk of our research. By the time I had met Professor Tipping, I was so familiar with our day-to-day work that no further introductions to their objectives and procedures were necessary.

It was not until my first fieldwork trip that I realized I had signed up for a lot of muddy work. Every two weeks, Professor Tipping takes me and my co-worker to our four sampling sites, which monitor the Ribble catchment, a river drainage basin. We collect water samples, perform maintenance on the auto-sampler bases



and probe, replace bottles, and record data. Collected samples are taken back to the lab for filtration and the isolation of carbon, nitrogen and phosphorus in the sediment. Filter papers with high concentrations of sediment are further analyzed and treated for organic material removal by muffle, and for inorganic carbonate removal by fuming.

The NERC Macronutrient Cycles (MC) Program has identified three research catchments for laboratory studies: Ribble, Conwy, and Avon. Additionally, we work with the catchment of the River Dee in Scotland to broaden our array of carbon-rich environments. All four catchments represent a range of land types, climates, and atmospheric depositions. Partnerships with various universities, institutes, and research centers throughout the UK allow the collection and transfer of samples from many waterways to our research site. We receive five-liter samples from waterways around the UK and then test their pH, conductivity, light absorption, and nutrient levels. All of these samples are spun in the centrifuge, purified using hydrochloric acid, and are then sent to the NERC Radiocarbon facility to be further analyzed for radiocarbon content.

The LTLS project brings together a range of expertise and involves the large scale integration of scientific models and natural systems. While it is headed by Professor Tipping, many individuals from other CEH sites, NERC, and even institutes outside of the UK contribute to the project. I am personally involved in the acquisition of new data on the topsoil and subsoil carbon, nitrogen and phosphorus pools, and radiocarbon contents. The purpose of acquiring this new data through fieldwork is to fill in gaps within the information already available, drive integrated simulation models, and use the data to predict future changes in nutrient cycles.

In my time here, I have learned many unexpected things beyond biogeochemical science. I have learned how research centers operate, the constraints of funding, the quirks of scientists, and the significance of independent time management. Most of all, I have learned what I am capable of, and this is the most important lesson I will take away from my first co-op experience. ■

Innovating for a Better World

BY ADANYA LUSTIG, UNDECLARED, 2018

Spotlight on Senior Engineering Capstones



Photo courtesy of Aidan Carroll



Creating a Cost-Effective Wind Turbine

Mechanical engineering major Aidan Carroll seems at home amidst the clangings and crashes of the mechanical engineering build space. Only glancing up at the occasionally loud whir of a machine, it's clear he's used to focusing amid the noise. And focus he must, in order to create a cost-effective wind turbine alongside fellow engineering students Ryan Kist, Kaylie McTiernan, Westy Ford, and Alexander John Manley-Helton.

Carroll described the process of testing the turbines in the Northeastern wind tunnel. "We're looking at different number of blades, different amount of sail, different amount of blade area, and how the blades are oriented to the wind," said Carroll. "We're trying to do comparisons, like is it better to have six blades or eight blades if all other factors are equal?"

These comparisons all lead to one thing: efficiency. The group is hoping to get to a coefficient of 0.3, which means that the turbine extracts 30 percent of the energy available in a given area of wind. The most that is theoretically possible is 60 percent.

"A lot of these projects are relatively open-ended," said Carroll. "For us, we had to decide: what is our power we need to produce, what is our pay-back period, where does it have to be located, are we trying to do this at 3 meters per second, 6 meters per second, 9 meters per second?" The group's largest requirements are that the turbine needs to be able to produce 500 watts at low wind speeds and pay for itself within five years. "The hardest part is naming down what your design requirements are, knowing how you define success," said Carroll.

Changing Blood to Type O with Enzymes

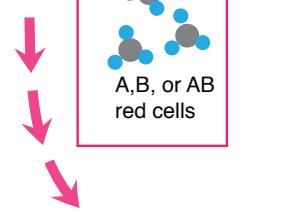
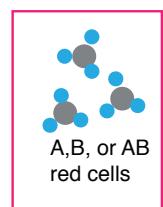
Chemical engineering majors Alyssa D'Antonio, Megan Bishoff, and Briana Lauziere are looking into a device that would enzymatically convert type B blood to type O. While they don't have to actually build the device for the project, they do have to make sure the science checks out and design such a device. They've looked at the research and picked an enzyme, although they're still in the process of designing the unit. "We're thinking right now we'll have people ship the blood to us, we'll convert it, and then ship it back to them, and we'll charge them the fee of converting the blood," said D'Antonio.

One of the difficulties the group faces is making the device economically feasible. "We

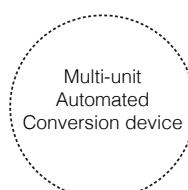
started this with the idea we'll sell the unit to hospitals and blood banks, and just train the people there to do it, so they'll always have that blood, but then we realized, well then our company has a short life span," said D'Antonio. "What happens if we sell to all of them? If we switch it to us doing the service, we'll always be in business. People always need blood, that's never going to change."

In addition to the economic difficulty of keeping the hypothetical business afloat, there's also the cost, both economic and otherwise, of production to consider. "They're not really economically feasible. We're hoping with our modifications we can make money," said D'Antonio. "It's hard enough to get blood from people; why take the blood you have and risk

1. Pre-Wash



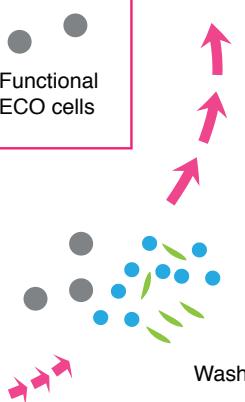
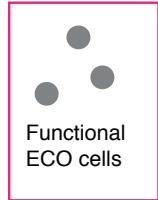
2. Convert



Incubate at RT
for 1 h

4. Re-suspend

In additive solution of choice



3. Wash



(Left to right) Photos courtesy of Calthopre, Calthopre and Wiki Commons

ruining it? You have to have the process perfect before testing."

The group wanted a project that could do good for everyone. "When we went into choosing our topic we wanted something that's interesting to all of us and it'll also have an impact on more than just, say, the United States or a certain demographic of people," said D'Antonio. "Everyone needs a blood transfusion, it's not going to discriminate, anyone can get it, and you can expand all over the world."

While the group would not pursue this beyond the school project, they've gained valuable knowledge about the process of enzymatically converting blood.

Converting Non-recyclable Plastic Waste into Energy

One group of environmentally-inclined seniors are looking to convert non-recyclable plastic waste into usable energy through a process called gasification. Kristen Coletti, Devin Hersey, and Katherine Sammon are looking into gasification because, while it's relatively new for plastics, it's been tested for other substances successfully.

Gasification requires heating up a stream of plastic to 800 or 900 degrees Celsius so the plastics break down, releasing gases that the process overseers then capture. The gases they're looking to collect are carbon monoxide, carbon dioxide, hydrogen, and nitrogen, called a "syngas."

"We're considering using that to heat up a secondary tank of water to make steam so we can put it through a second turbine, get more electricity out of it, and then hopefully sell off the syngas," said Coletti. "It's not going to be easy to dispose of because it has carbon dioxide and carbon monoxide in it, and you can't release those into the atmosphere. Big petroleum companies will buy syngas and use it in their processing."

While the group knew from the start they



Focusing on the four major design components, and figuring out where we want to get in each of them is where we're at now."

"It's a project that's in progress right now in the real world," said Sanchez. "The Chinese government is looking to develop an eco-city on this exact site. That's the point of capstoning, you want to do something real-life applicable."

Redeveloping the Civil Infrastructure of a Mumbai Slum

Liz Cherchia, Kevin Rathbun, Andrew Rohrman, Brad Johnson, and Caitlin Candee took on a project large in scope when they chose a project a little further from home. "So our project is under the environmental engineering capstone," begins Candee. "We hijacked it a little bit from the teacher's original plan. We wanted to do a capstone that was in the developing world, and we decided we wanted to do an urban one. So ours is redeveloping the civil infrastructure of a slum in Mumbai."

The slum in question, Dharavi, is unlike a typical slum, or how one might picture a typical slum. Dharavi is home to a thriving economy, a low crime-rate, rich social life, and power-wielding millionaires. "Everything as a society about it really works, except children are dying of cholera," said Cherchia. "It's an interesting dichotomy of a place with a billion-dollar economy and a really well-developed society, and a place where there are literal rivers of human waste."

The group wants to make a plan that only improves upon the neighborhood, not replaces it, like some plans aim to do. Their main focus will be on clean water, wastewater, stormwater, transportation, and urban planning. "There have been a few redevelopment plans in the past [in Dharavi] because it's incredibly valuable real estate," said Candee. "Our approach is different, because we're starting from a place of trying to make the space work better for the current inhabitants instead of trying to throw them all into a high-rise and sell off the rest of it off for commercial real estate development."

The complicated situation in Dharavi makes the group wonder what the best course of action is, especially because they don't want to push the poorest people out of their homes with high prices. "It's incredibly difficult to understand what's going on, and we're not pretending to, but the project is to put in civil infrastructure," said Cherchia. "Partially because we are a civil engineering capstone, but also because it's the only thing Dharavi really lacks." ■

wanted to convert waste into usable energy, it wasn't until they happened upon gasification of plastics that they decided non-recyclable plastics would be their starting point. "We were just sitting in the lab and one of the other students mentioned some project about some guy in Japan converting plastic waste into electricity, but by pyrolysis, which is similar to gasification, but it's in the absence of oxygen," said Hersey. "So we looked more into it and stumbled upon an article about gasification, a new technology that hadn't been studied a lot, so we were like, 'Okay, let's do this.'"

While the group finds the technology promising, they think it's not already being put into action in the private sector because it's not economically feasible without government subsidies and support. However, working on the engineering capstone can help students realize the difficulty of obtaining the funding required for such fantastic projects.

Designing a City that Lives and Breathes

Imagine a city that lives and breathes. That's what Ezgi Kosereisoglu, Miller Huffman, Sarah Sanchez, Lewis Raibley, and Ruize Sun are trying to design. "There's no one definition for what an eco-city is. One of the major ways our group is looking at an eco-city is to consider it an ecologically healthy city, to look at it like a living organism," said Sanchez. "Eco-cities include ways to balance both global and local perspectives. It involves an idea known as urban metabolism, which goes along with looking at it as an organism."

The team has been tasked with creating such an eco-city in Yuelai, China. "For our project we were given an initial design that was done by a company, Calthorpe. They designed an initial layout, the master plan of the city," said Sanchez. "We've been working off of that, we've done some design in the urban planning field, where do we want the schools to go, and what type of schools, where are we going to put the hospital, the equivalent to city hall. Then the other major engineering design aspects that we're covering are transportation, wastewater, stormwater, and green infrastructure."

As simple as Sanchez makes the design process sound, they encountered difficulty deciding just how much of the city to design. "At the beginning of this project none of us had experience in urban planning, and so the scope of the project, the whole city, was huge," said Sanchez. "We had to set some parameters.

Northeastern Adds New Department of Bioengineering

An Interview with Interim Chair Lee Makowski

BY JOHN JAMIESON, CHEMICAL ENGINEERING, 2015

Northeastern students and faculty alike are thrilled about Northeastern's recent announcement of a department of bioengineering within the College of Engineering (CoE). The bioengineering department will provide students and faculty members with exciting new research opportunities in tissue engineering, biodevices, biomechanics, and nanotechnology. New bioengineering master's and bachelor's degree programs are currently in development, and will join the existing PhD program in bioengineering already offered by Northeastern.

The interim chair of this exciting new department is Dr. Lee Makowski, who joined Northeastern in the fall of 2010 as an interdisciplinary faculty member in the Electrical and Computer Engineering, and Chemistry and Chemical Biology Departments. NUScience had the opportunity to sit down with him and discuss Northeastern's newest department.

What is bioengineering?

There are many definitions out there, depending on who you ask. Here at Northeastern, we have decided on "engineering in a biological context." In traditional engineering, you work with a variety of materials, and you encounter things like acceptable tolerances. In bioengineering, you grapple with these same kinds of themes, only the system is biological in nature. It could be the human body, or a bioreactor. Maybe you are working on turning biomass into biofuels, or imaging biological tissues.

Where did the idea come from to create a bioengineering department at NU?

Jeffrey Ruberti, now an associate professor in the mechanical and industrial engineering departments, with a secondary appointment in chemical engineering, should be credited with bringing bioengineering to Northeastern. He created the PhD program in bioengineering 4 to 5 years ago. It was an interdisciplinary collaboration between the College of Engineering, College of Science, and Bouvé College of Health Sciences. Faculty from each of these three colleges could advise bioengineering PhD students. A few years later, an external advisory committee recommended that a group of faculty members should be assembled to answer the question, "What should Northeastern be doing in bioengineering?" A group of 6 to 8 faculty members got together, selected me to chair the committee, and concluded by evaluation that Northeastern would benefit greatly from the addition of a distinct bioengineering department.

What is the process like for creating a new department?

It's been a long time since a new department was created at Northeastern. In fact, as we started to do this and answer that question, no one that we asked was really sure when Northeastern's youngest department was created, or even which department that was. To some extent we had to learn the approval process as we went. During the 2011-2012 school year, the faculty committee presented its proposal to the new Dean of the College of Engineering, Dr. Nadine Aubrey. Dean Aubrey welcomed the idea and in 2013 decided that it was time to move the project forward. The faculty approved the department in a rare unanimous vote. Then the Student Senate and the Board of Trustees both gave their nods. Now we officially have a department with three faculty so far: Jeff Ruberti, Anand Asthigiri, and myself.

What has been the biggest challenge so far?

Avoiding the "seven-year bachelor's program." The question is this: How do we design a curriculum which incorporates more biology while still delivering the same rigorous engineering classes that an undergraduate engineer needs to be prepared for his or her career? In addition, we expect that many of the students will be on a pre-med track, so we're working to make the curriculum compatible with that program as well. We have excellent ideas for a number of classes which would teach topics pertinent to bioengineering, but the challenge is to carefully choose which courses to add, substitute, or merge in order to create a curriculum that fits neatly into a standard five-year format. It's really a fascinating problem.

What are you working on now?

Currently, we're focused on getting the master's curriculum approved by the university and further developing the bachelor's curriculum. Right now we're looking at getting about 20 new courses approved by the Student Senate. The master's program is targeted to students who received a bachelor's in any of the engineering disciplines, but would like to learn more about bioengineering. We've identified three different concentrations that we'll offer, each of which has some alignment with another engineering discipline. One branch, associated with mechanical engineering, will focus on devices, such as implants and prostheses. A second, related to electrical engineering, will cover biomedical imaging, as well as signal



and data processing. A third, related most closely to chemical engineering, covers the topics of synthetic biology, systems, and tissue engineering. We're also working on bringing in a permanent chair for the department. The committee is looking for a candidate with strong leadership and entrepreneurial skills, a vision for building an integrated department with strong research, and fabulous teaching. We believe that will be the best way to strengthen the university, and provide students with the best experience they can have.

How soon will students be able to enroll in the graduate and undergraduate programs?

Pending the approval of the curriculum, we expect that graduate students enrolling in the fall of 2015 will be the first group with the option of obtaining a master's in bioengineering. For the bachelor's program, we also expect that the fall of 2015 will be the first time these courses are offered. However, since the freshman curriculum is shared by all engineering disciplines, the freshman entering in 2014 should be able to switch into the program their sophomore year without having missed any discipline-specific classes.

Why did you think NU should have a department for bioengineering?

Opportunities for students. If we look at growth in the engineering disciplines, no field is growing faster than bioengineering, and that trend is expected to continue throughout the next 20 years. Students will be able to benefit on two levels: first, through the research of faculty, and second, through their bioengineering-based co-ops. Considering the number of cutting-edge biotechnology companies in the Boston area, as well as the incredible Boston hospitals, really the question should be, why not bioengineering at NU? ■

Understanding Dream Recall

BY NAOMI STAPLETON, PSYCHOLOGY, 2016

Picture the scene: You burst through the door for your 8 a.m. class, just in time. You feel the relief wash over you—but no, that's not relief. That prickling, trickling feeling is sweat. With a shock, you come to the conclusion that you are stark naked. Luckily, just before your professor opens his mouth to ask your intentions, you wake up panting in your bed, very much clothed and confused.

Many people are haunted by the horrifying, the mundane, and the just plain weird situations that the brain imagines during the night, whereas others remain blissfully unaware of these midnight musings. Scientists can still only speculate about the function of dreams, but they are getting closer to understanding why humans exhibit drastically different levels of dream recall.

In INSERM's (Institut national de la santé et de la recherche médicale) Brain

Dynamics and Cognition Team's recent sleep study, researchers used Positron Emission Tomography (PET) to analyze the brain activity of 41 participants during sleep and wakefulness. These subjects were distinguished based on their dream recollection: "high dream recallers" who recall dreams an average of 5.2 mornings per week and "low dream recallers" who recall an average of 2 per month. The PET results highlighted clear differences in the participants' brain activity throughout the night.

High dream recallers awoke more often while sleeping, and were generally more reactive to external auditory stimuli during both sleep and wakefulness. The high dream recallers exhibited higher spontaneous activity in the temporo-parietal junction and the medial prefrontal cortex in the brain. These areas serve as information-processing centers and are involved in transferring the brain's attention to

external stimuli. Therefore, increased activity in this area could be what promotes increased wakefulness between sleep cycles. A brief awakening after a dream is likely what facilitates high dream recallers' greater encoding of the dream memory, since "the sleeping brain is not capable of memorizing new information; it needs to awaken to be able to do that," said INSERM Research Fellow Perrine Ruby.

It is clear that the increased activity in the temporo-parietal junction contributes to a higher likelihood of dream memorization, but it is not yet certain whether the degree of dream production could also be a factor. INSERM, a public health and biomedical research institution in France, team hopes to expand their research in the Lyon Neuroscience Research Center in the future to account for and examine the dream production's role in dream recall. ■



Neurogenesis

noun. - growth and development of neural tissue

BY CHRIS DAYARAMINI, HEALTH SCIENCE, 2017

The nuclear bomb has taken a devastating toll over the past few decades, however, new research utilizing some unintentional effects of the weapon that once wreaked havoc on the world may save millions of lives in the future. Over 50 years ago, a series of above-ground bomb tests were conducted and subsequently released copious amounts of the radioactive carbon-14 isotope (14C) into the atmosphere. This 14C penetrates the DNA of propagating neurons and allows determination of the age of the cells by comparing the ratio of the radioactive 14C isotope to the normal 12C isotope in the cells; there are lower amounts of 14C in newer cells, whereas the quantity of 12C stays constant.

Jonas Frisén and his team at the Karolinska Institute in Stockholm, Sweden looked at the 14C concentration in the DNA of various neurons in the brains of deceased patients. He was able to determine, through the use of retrospective carbon dating, that humans

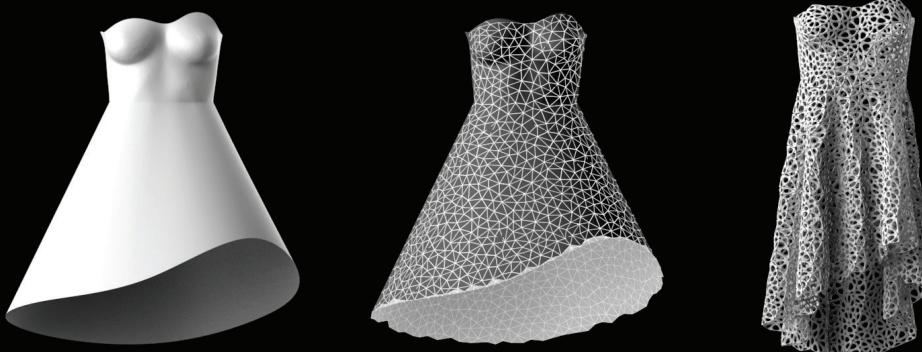
are capable of a significantly large amount of neurogenesis in the hippocampus, and that it may directly contribute to brain function. Gerd Kempermann of the German Center for Neurodegenerative Diseases, who had no relation to the study, told *The Scientist*, "It's a very impressive achievement... It's welcome to the field as a long-sought confirmation, but it's also more, because they model the dynamics" of neurogenesis and suggest its function in the human brain. Neurogenesis had previously been found in humans in 1998, but substances used in the methods of that trial were banned shortly after, so the results were unreplicable and subsequently deemed inconclusive.

Neurons of a mouse's hippocampus are well-known to regenerate, so until more information on human neurogenesis arises, they can be used as an approximate model. Their newly generated neurons, however, can more easily alter the strength of neural connections in response to stimuli. "These [young cells] are

required for separating similar experiences as distinct memories... For us that means telling apart the Beatles and the Rolling Stones, rather than lumping the two together as rock and roll music," Frisén explained to *The Scientist*. Also noted in mice is that a lack of neurogenesis is associated with psychiatric disease. This, along with his own findings, has caused Frisén to believe that these new neurons may play an important role in mood regulation. For now, speculation on possible applications will have to be based on what is known about animal neurogenesis until more work is done on this capacity in humans. Only time will tell exactly which, if any, diseases this discovery will help cure, but the possibilities are rather exciting. ■

Art by Science

BY KAYLA GOMES, PHYSICAL THERAPY, 2017



A Concept Dress Designed with the Kinematics 4D Printing System. Photo by Nervous System.

Achieving harmony between math, science, and art may be difficult, but Nervous System, a boutique based in Somerville, uses natural phenomena as inspiration for their designs, creating work that can itself evolve.

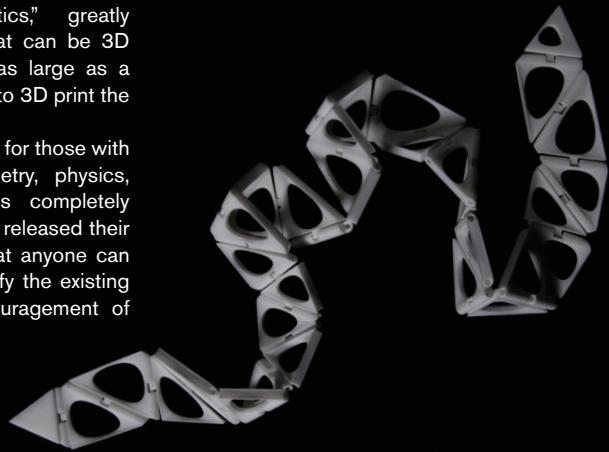
According to its company website, Nervous System (NS) "focuses on generative design methods using both algorithmic and physical tools to create innovative products and environments." Observing natural occurrences such as coral formation, leaf venation, dendritic growth, and cell formation, NS formulates algorithms and software to make jewelry, lighting, puzzles, and more. This software uses biological forces like cell division and physical forces like attraction and repulsion to warp and bend an initial design to create something truly unique.

There seems to be no limits for what NS can do. In a case study from the company's

blog, NS scanned a woman's body, sketched a dress from those measurements, and created a 3D printed dress made out of thousands of tessellated, interlocking plastic parts. This technique, dubbed "Kinematics," greatly expands the possibilities of what can be 3D printed; it can fold something as large as a dress into a shape small enough to 3D print the item in one piece.

What may seem possible only for those with expansive knowledge in geometry, physics, and computer programming is completely accessible to the public. NS has released their software on their website so that anyone can create their own pieces or modify the existing code to their liking. This encouragement of

discovery and innovation open to the public, as well as their own work, emphasizes what NS is truly trying to achieve: a generative, open process. ■



Stronger Muscles Facilitated by Fishing Line

BY JOSHUA COLLS, BIOLOGY, 2016

Anatomical scientists are perpetually striving to innovate new methods for refining the efficiency and output of the human body. Whether it is through remedial disease treatment or alternatives in synthetic bodily functions, the quest for improvement never ceases.

In a study published in the journal *Science* in February of 2014, material scientists at the University of Texas at Dallas pioneered the insertion and synthesis of fishing line, or nylon fibers, into the human muscle system. Ironically, this groundbreaking corporal achievement is carried out rather simplistically. Through a careful nylon coiling under a specified tension, relative to where the fiber will be placed in the body, the thread will begin to fold on itself. Once

heat-treated, the coils contract like muscles, making them applicable for use in the human body.

Of course, artificial muscles have been manufactured before, so how is this any different from previous work with manmade muscle replacements? This ever-so simplistic design allows the coils to have about 100 times the strength of human muscle of the same length and weight, allowing them to withstand and lift weight heavier than an ordinary human muscle ever could. While this type of artificial strength has been developed before, it has never cost as little, weighed so light, been as strong and durable, and come in the variety of sizes possible with this new research. These new synthetic muscles can generate around 7.1

horsepower per kilogram of thread. That kind of power is comparable to that of a jet engine.

Although human trials remain in the foreground, the scientists have also implemented the design for other practical, worthwhile, and immediate uses such as exoskeleton suits, insertion into robotics for more precise microsurgery, motor replacement, and textile clothing that can dilate and contract its pores when in contact with a particular temperature.

The next step for scientists is to harness the ideal medium for these other applications. The developments in muscle efficacy and efficiency, as well as the scientific branching that this technology is pushing towards, are exciting for both scientists and potential subjects. ■

Seeing with Sound: Advances in Sensory Technology Open New Avenues for the Blind

BY GRACE SEVERANCE, BIOLOGY & PHILOSOPHY, 2018

Most people will never know what it's like to lose one of their five senses for an indefinite amount of time. Yet many people go about their days without experiencing the world through sight or sound—some for all their life. A recent publication by the Hebrew University of Jerusalem shows promising results for an unprecedented technology that would give blind people a chance to "see." The article describes a new technology called a sensory substitution device (SSD), a pair of sunglasses equipped with a camera, a small computer, and a pair of headphones. The camera records visual data and then transmits said data to the computer. The computer uses a predictable algorithm to convert the visual data into "soundscapes" which are played into the headphones of the users. Based upon which soundscape is emitted, the user can identify images ranging from locations of objects to even facial expressions.

Professor Amir Amedi, who leads the Center for Human Perception and Cognition at the Hebrew University of Jerusalem, has dedicated much of his research to alternative sensory methods. Through much investigation, he and his colleagues have found, "many brain areas are characterized by their computational task, and can be activated using senses other than the one commonly used for this task, even for people who were never exposed to 'original' sensory information at all (such as a person born blind that never saw one photon of light in his life)."

Despite the high success of the SSD, such technology is not widespread in the deaf community. The main reason for this is SSDs

are usually very cumbersome and difficult to use. In addition, most SSDs cannot provide color information; most users are dissatisfied with the device. However, thanks to these new advances in the technology, Amedi's EyeMusic version of the SSD is "much smaller and lighter, and they can run using a standard smartphone."

It's important to note that the soundscapes do not actually stimulate the brain to "see" the world as it is visually interpreted. The user must partake in many training sessions in order to recognize which soundscapes represent which images.

There is a very specific method for which the SSD translates the visual imagery. Amedi and his team scan various images and use musical pitch to represent where the pixels are located. The higher the pitch, the higher in the plane of view the image is. Conversely, a low pitch would mean that the image is located near the bottom of the plane of view. The timing of the musical notes signifies which side the image is on. If the picture is located on the left, then musical notes associated with that image will begin to play right at the opening cue. But if the image is located on the right, the notes will not come in until later during the soundscape. Color information, novel to Amedi's EyeMusic version of the SSD, is conveyed by the use of different instruments: white is expressed by vocals, blue by the trumpet, red by a reggae organ, yellow by the violin, and so on.

Seeing, and using the senses in general, seems to be a much more complicated task within the brain than is conventionally thought. The scientists at the University of Jerusalem believe that there is a whole network within the

human brain that is "dedicated to processing and perceiving of body shapes, starting from the areas processing vision in the cortex, leading to the 'Extrastriate Body Area,' or EBA, and further connecting to multiple brain areas deciphering people's motion in space, their feelings and intents." This hypothesis is further supported by studies with the blind, where the EBA of the blind was still connected to the network of body-processing found in people with functional vision. The idea suggests that the brain is much more flexible than originally believed and not just a sensory machine.

"The computer uses a predictable algorithm to convert the visual data into 'soundscapes' which are played by the headphones of the users."

Such developments in SSD technology may help to popularize it for the visually impaired population. Given how cheap and easy it is to use, it's quite possible that the EyeMusic SSD will become widespread in a few years, and further down the road, new capabilities that were previously unattainable may be available for the blind. Thanks to the EyeMusi SSD, in the coming years, the blind may start seeing in symphonies. ■



60 Years Later, Morphogenesis Reborn

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

Atrue Renaissance man, Alan Turing made significant discoveries across multiple fields, including computer science, mathematics, and biology. In Turing's last published paper before his death 60 years ago, he proposed a theory on how identical cells differentiate into different and more complex structures, such as feet and hands. The process he attempted to explain is called morphogenesis.

Turing approached this biological phenomenon through a chemical lens. He believed that cells differentiate and evolve

through intercellular reaction-diffusion. In this process, a group of chemicals react amongst each other and then diffuse, or spread, across a space. One example of this could be between the cells in an embryo.

Both excitatory and inhibitory agents mediate this reaction. An excitatory agent, such as the chemical compound bromine dioxide, starts the reaction, and an inhibitory agent, such as bromine, suppresses the reaction. When this reaction finishes, structurally different cells arise. Specifically, Turing predicted that these chemical reactions generate up to six different chemical structures, or patterns, one of which is responsible for differentiation.

Researchers at Brandeis University and the University of Pittsburgh devised a quantitative way to measure Turing's theory through a cellular chemical system consisting of different liquids.

Within these liquids, they created rings of synthetic cell-like structures that reacted through excitatory and inhibitory chemicals. When they ran the tests, they were able to find all six of Turing's chemical patterns, confirming his theory. However, they found a seventh structure, which was incorporated into the theory by including heterogeneity amongst cells.

Previously, Turing's theory has been thought as a useful conceptual framework, but nothing more. However, these findings may have an important implication: This type of reaction-diffusion chemistry can be used in the material science field to create softer, more fluid robots. They also have big implications for the study of biology.

Sixty years after death, the Renaissance Man lives on. ■

Alan Turing, 1912-1954 British Mathematician and Computer Scientist

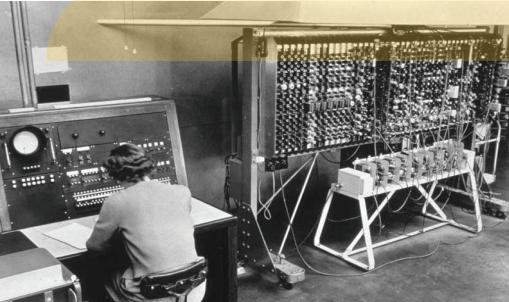
BY JESSICA MELANSON, JOURNALISM, 2014

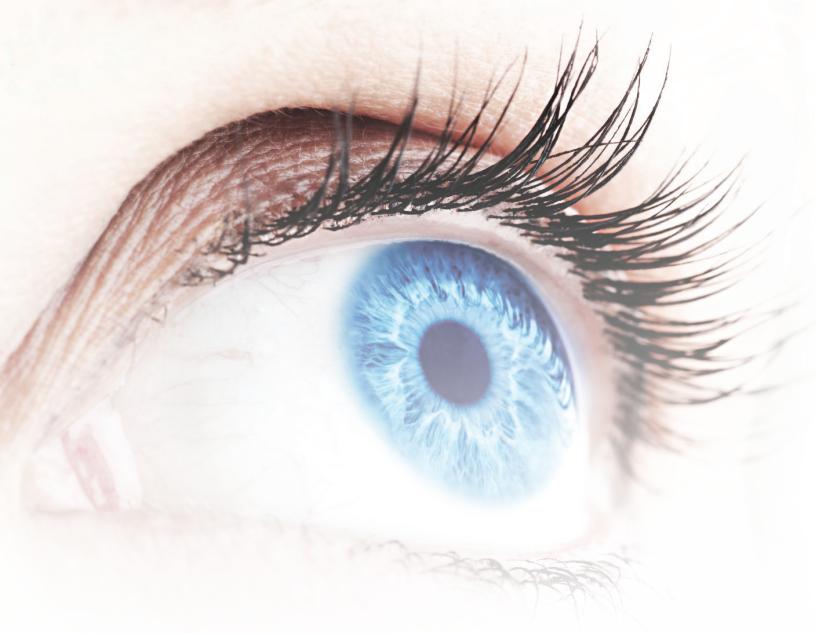
Alan Turing, a pioneer in his time, contributed enormously to the field of computer science. In his time as a student of Cambridge University in England (and later Princeton in the United States), he developed the "Turing machine" concept, a proof showing that computers cannot solve every math problem, which is now regarded as the cornerstone of computation theory.

At the outbreak of World War II, Turing joined the Government Code and Cypher School, Britain's division of cryptography, where he led the way in deciphering encoded messages from the German Enigma code machine. After the war's end, Turing worked at Britain's National Physical Laboratory, designing what could've been the computer with the highest computation speeds of the time, only to have his

work discredited by colleagues. He left in 1948, and soon started work at Manchester University directing the computer science lab and exploring the vast potential of AI.

His good reputation and high security clearance hit a roadblock, though—in 1952, he was convicted of homosexuality, and the once-revered code-breaker was no longer welcome to serve in Britain's secret government programs. Though his suicide in 1954 was a catastrophic loss for the field of computer science, Turing's work in chemistry, featured here, has seen a revival 60 years later—vindicating the man once regarded as the eccentric, but effective, code-breaking genius of Britain. ■





Improved Vision? There's an App for That!

BY MICHAEL MURRAY, ENGLISH & COMPUTER SCIENCE, 2014

People looking to heighten their sense of sight may now have a surprising alternative, one accessible from the comfort of their own home. A recent app for the iPad, ULTIMEYES, claims to offer users a way to strengthen their vision through its regular use. Many harbor their doubts about the effectiveness of its approach, but the app continues to earn new sales.

UltimEyes was created by Aaron Seitz, a neuroscientist at the University of California Riverside. He states that the app relies on neuroplasticity, the ability of the brain to rewire itself, in order to strengthen the neurological portion of sight. By having the user perform increasingly difficult visual challenges, such as choosing a hard-to-see target while avoiding similar decoys, they reinforce the pathways in the brain used to see details. Theoretically, this process would allow them to improve regular eyesight or prevent the deterioration of vision due to age.

“Athletes showed a significant improvement, some experiencing as much as a 31% increase in vision after two months of regular training.”

The improvements are purely neurological, so the app can't fix problems stemming from physical features of the eye. Most nearsightedness and farsightedness, which is a product of the actual shape of a person's eye, would not be affected by this sort of training. They may still experience some improvement, but likely could never reach 20/20 vision.

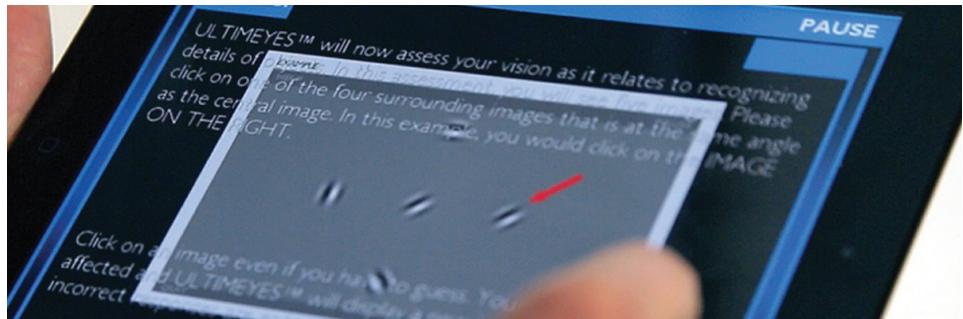


Photo courtesy of brandsynario.

NUSCIENCE INVESTIGATES

BY CHELSEA CANEDY, BEHAVIORAL NEUROSCIENCE, 2018

As exciting as this sounds, the app has been criticized for the methodology of the research supporting its effectiveness. Conducted without a control group, the participants were all members of either the university's baseball or softball teams, groups with statistically better vision than the rest of the population. Despite this, the athletes showed a significant improvement, some experiencing as much as a 31% increase in vision after two months of regular training with ULTIMEYES. Seitz hopes to confirm his initial findings with better data by eventually adding an opt-in feature to the app which would allow users to submit their scores over time. With over 20,000 sales, tapping into the customers as a data resource could provide a better sample size for proving the app's effectiveness.

Currently, UltimEyes is only available for iPad, with Android and iPhone support expected soon. ■

rowing up I, like most children, dreamed of having super powers. From super strength to mind reading, I could always envision myself as each of those beloved comic book heroes. That is why when I saw an app that could produce superhuman sight I was both intrigued and skeptical. I was familiar of this type of perceptual learning in children, but I had not heard of it in adult models so naturally I wanted to see for myself, and I did.

After purchasing the ULTIMEYES app, I used a Snellen eye test from 20 feet away to measure my current vision. I found that through the self test I currently have 20/30 vision. For the next two weeks I used this marker as a baseline while re-testing my vision after every two sessions (or twice a week). I chose settings that would improve my long distance vision, since I am still working for my superhuman sight. After a calibration phase of visual tasks of varying difficulty, I began the strengthening activities. Some require you to click as many random shapes, called Gabors, as possible during a given time period. Others require you to click on the Gabors as they appear on the screen. After my six sessions, I noticed very little, if any, visual improvement. My eyesight is sadly still 20/30, though the website recommends each individual complete thirty 25 minute sessions before results are known, so I recommend trying it yourself! ■

The Highs and Lows of Estrogen

BY JORDYN HANOVER, BEHAVIORAL NEUROSCIENCE, 2017

Over 10 years ago, studies suggested that estrogen, the primary female sex hormone, could be used as an antidepressant. Currently, there are many conflicting opinions on whether estrogen should be used as an antidepressant, if it is clinically possible, as estrogen in high doses can cause depression. Additionally, certain types of breast cancer have been proven to be estrogen-dependent, and most are susceptible to at least some influence by estrogen. In these cases, estrogen feeds the cancer and sustains its growth. Pursuing safer estrogen therapy, treatments for depression using estrogen have continued to develop.

Recent reports have shown that estrogen in females regulates the role of monoaminergic neurons, which secrete mood-regulating neurotransmitters such as dopamine and serotonin. Due to the large role that they play in regulating mood, a deficiency of monoaminergic neurons can sometimes lead to depression. The reports also indicated that the incidence of depression aligned with estrogen shifts throughout a female's life cycle. Examples included postpartum depression, in which women become depressed after delivering a child, as well as depression during perimenopause—periods in which estrogen levels are known to be extremely low.

“Incidence of depression aligned with estrogen shifts throughout a female's life cycle.”

There are many different types and subtypes of estrogens. One of these is 17-Beta Estradiol, a natural estrogen subtype which has been identified as a possible antidepressant when administered during the postpartum and perimenopause periods. However, identifying the correct dose and hormonal balance has proven to be difficult, especially as some antidepressant

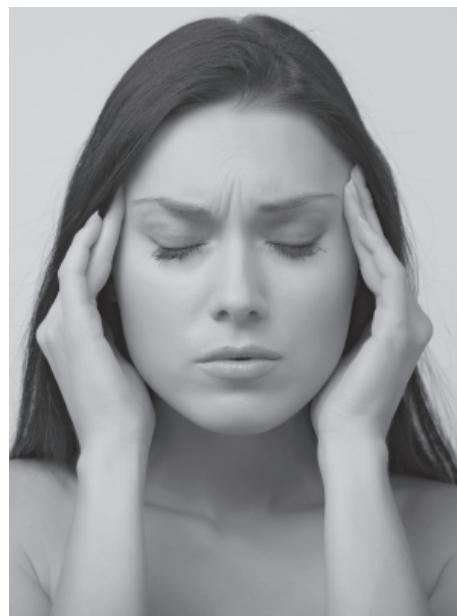


Photo Courtesy of Renochiropractic

drugs approved for market sales have been shown to have weak but significant estrogenic properties.

In February 2014, a research team used an assay to determine that an antidepressant compound exhibits an estrogenic effect and that weak estrogenic correlation could contribute to the growth of breast tumors, 70 percent of which are sensitive to estrogen. The assay also found two other drugs to act as anti-estrogens, which inhibit the enzymatic conversion of hormones into estrogen, and are sometimes used to prevent breast cancer. This implies that these drugs could possibly be used to prevent the growth of cancerous tumors in breast cancer patients.

The new test, called AroER tri-screen, can analyze compounds' effects on estrogen and the androgen-converting enzyme aromatase for over 1,000 compounds, including Paxil, a common antidepressant. This screening revealed that Paxil acts as an endocrine disrupting compound

and may, in fact, contribute to the growing rate of breast cancer. Compared to other antidepressants, a recent study found that patients taking Paxil were more likely to succumb to breast cancer, and that several enzymes were being disrupted, not just those that are estrogen-related.

The new testing method has since identified several compounds as having estrogenic or anti-estrogenic properties, and also confirmed those properties for several well-known endocrine disruptors. Lead study author, Shiuan Chen, expressed hopes that AroER tri-screen can be used to help explain why certain drugs and drug combinations are more or less effective, as well as identify the effects new chemicals will have on estrogen and other endocrine hormones.

The information that hormone replacement therapy can lead to diseases like heart disease, breast cancer, and stroke is not new. Twelve years ago, the Women's Health Initiative showed that replacement hormone therapy led to as much as over 20 percent increased risk of developing breast cancer. The idea that estrogen can sometimes be used as a natural antidepressant has also been considered for several years in the scientific community. In the future, however, the key will be to focus on finding the right concentration of estrogen and discovering ways to safely synthesize bioidentical hormones such that scientists can find the “sweet spot:” the coveted point at which estrogen is an efficient antidepressant, but not so abundant that it will cause cancer cell growth and tumor development.

Several studies have also looked at the potential links between testosterone and antidepressant effects, but found no significant data. This implies that estrogen levels are the only sex hormone levels that affect the occurrence of depression. The absence of a link between testosterone levels and depression suggests that, as more is learned about the antidepressant properties of estrogen, it may only be a viable hormonal solution for women. ■

NUScience Explains: DNA Sequencers

BY JOSHUA TIMMONS, BIOLOGY, 2016

When you picture the next generation of DNA sequencers, don't think big—think small. That's the message accompanying Oxford Nanopore Technology's newest USB-sized sequencer, the MinION. Fifteen years ago it took four supercomputers, with 7,000 processors, almost a year to sequence the human genome. So when Oxford Nanopore Technology says that their large scale technology will soon be able to sequence an entire human genome in 15 minutes, it's understandably a big deal. One should keep in mind, however, that those supercomputers mentioned were from the stone ages of shotgun sequencing and algorithms. The future is here, and it's electrical sensing nanopores.

In mid-February, Oxford sent out its first batch of beta-ready MinIONs utilizing this technology. For the cost of shipping, anyone could have access to the world's first commercially available nanopore sequencer. Nanopores, two decades in the making, use characteristic variations in an ionic current to detect the nucleotides of DNA strands as they are pulled through via electrostatic forces.

Unfortunately, preliminary results have been something of a letdown: average read lengths are just five thousand bases long. While this individual read length is longer than any other technology out there, it's far short of the human genome's three billion base pairs. The upshot is that these sequencers are the pinnacle of portable and completely disposable after use. By product release, these little sequencers have huge potential for researchers wanting the full genetic makeup of microbes with vastly smaller genomes.

Not to be outdone, Illumina's new product HiSeqX went on sale in January. For only \$10 million, anyone can be the proud owner of a HiSeqX Ten Sequencing System. What does that price tag get you? Well, ten "ultrahigh" throughput sequencers capable of fully sequencing 20,000 human genomes per year.

The company claims this new system will produce entire genomes for only \$999 apiece. This new price tag, one millionth the cost of the Human Genome Project, represents an important milestone: sequencer companies have been promising thousand-dollar genomes for over a

year, to no avail. Whether HiSeqX is the horse to win the race remains to be seen, especially since speculators think a thousand dollars is an understatement. Regardless, MIT, Macrogen, Garvan Institute, and J. Craig Venter Institute have already bought in (with Venter signing up for two systems).

A graph showing the price of sequencing a human genome looks like the inverse of Moore's law, with cost falling at a consistently exponential rate. So while HiSeqX machines lack the new car smell of nanopores, it's the next step in a market defined by consistent price drops.

With cryptocurrency speculation lacking the excitement it once had, the competitive world of DNA sequencing may be the next best thing. If these niche technology proponents are correct, we could each have our genomes sequenced within the decade; maybe then we can find some medically actionable reason for doing so. ■

Harnessing the Sun's Power: The Advent of Nuclear Fusion

BY JUSTINE BELINSKY, BIOLOGY, 2017

Most of the sources of energy used today, including fossil fuels, solar power or wind power, are either limited or inefficient. One of these developing sources is nuclear energy and the Lawrence Livermore National Laboratory (LLNL) in Livermore, California has recently made a big step towards making nuclear energy more efficient. This facility houses the world's largest high energy laser, the National Ignition Facility (NIF), which is made out of 192 laser beams that converge in a region called the Target Chamber. Thanks to the principle researcher for this project, Omar Hurricane, and his team, the NIF has recently achieved nuclear fusion, which could someday provide tremendous amounts of energy if harnessed effectively.

Nuclear fusion occurs when two isotopes of hydrogen, with one proton each, are combined to create helium, an atom with two protons. While this process creates a lot of energy, more energy was put into creating it than was generated. In the future, scientists at the NIF hope to not only lower this energy barrier but also to achieve "ignition", the name given to the process where fusion feeds on itself to continually create more

energy. With a nuclear fusion power plant, energy will be able to be generated without greenhouse gases, toxic emissions, or radioactive wastes.

The laser at the NIF works by exciting electrons in gases, glasses or crystals, which will emit photons when they return to their ground state. Laser light differs from normal visible light

“The laser...is creating 500 trillion watts of power, which is about 100 times more power than any other laser facility.”

in that every electron in a laser emits the same wavelength of light, and the light is directional and coherent. One amazing feat that the NIF has accomplished is creating a system of lasers capable of focusing 500 trillion watts of power into a chamber the size of a pencil, more than

100 times the power of any other laser facility.

In addition to its successes in nuclear fusion, the NIF has been used for other projects as well. For example, the NIF is used to help national security by replicating conditions in nuclear weapons. Many of the nuclear weapons owned by the United States are twenty to forty years old, and so the NIF is crucial for examining the changes these weapons will go through over time. Another success of the NIF has been creating densities greater than the density at the center of the Sun. If this density can be further increased threefold, ignition will be possible.

Although the ultimate goal of ignition has yet to be attained with the total ratio of fusion energy out to laser energy in at just 1 percent, the NIF laser has the potential to release up to 100 times the amount of energy needed to start the reaction. By eventually reaching ignition, the use of nuclear fusion will create usable energy without harming the environment. Ultimately, the same form of energy that keeps the sun burning may be able to be harnessed for energy production here on Earth. ■



Wifi Goes Viral

BY OLOLADE AKINGBADE, BEHAVIORAL NEUROSCIENCE, 2018

Computer scientists at the University of Liverpool have engineered a virus like no other. Known as "Chameleon," the computer virus is designed to spread airborne through wireless connection networks and is as swift as the common cold.

Researchers at the University of Liverpool's School of Computer Science and Electrical Engineering and Electronics simulated an attack with the programmed virus, finding that it spread easily via WiFi access, bypassing encryption and detection points. They have compared the action of Chameleon to a contagious and airborne pathological virus, moving between nearby homes and businesses by way of WiFi network access points.

The attack was simulated in a laboratory setting based on the infrastructural and wireless network models of the cities of London and Belfast. In regions of high population density with wireless access points in close proximity, virus propagation occurred quickly. Chameleon even bypassed secure and protected WiFi networks, by taking advantage of weak networks and WiFi access points without password protection. Because Chameleon operates through WiFi rather than the internet, it avoids detection, as most virus detection systems are internet-based.

"WiFi connections are increasingly a target for computer hackers because of well-documented security vulnerabilities, which make

it difficult to detect and defend against a virus," said Alan Marshall, professor of network security. "...We are now able to use the data generated from this study to develop a new technique to identify when an attack is likely."

The university's work sets a precedent, showing for the first time that WiFi networks can be points of quick-spread viral infection. The lab hopes their simulation will serve as a model for understanding new mediums of viral computer infection, as well as for improvement in information security. ■

Yellowstone Releasing Helium

BY MATTHEW TYLER, MARINE BIOLOGY AND ENVIRONMENTAL SCIENCE, 2017



The recent release of helium gas from Yellowstone National Park rock has received perhaps undue attention from two groups of people: those familiar with the massive Yellowstone super-volcano, who think this phenomenon signifies the end of the world as we know it, and those familiar with the helium shortage in the U.S., who think this can be used to bolster the supply.

A study from the journal *Nature*, as well as input from its authors, explains that both of them are wrong: the former because, as lead author Jacob Lowenstern says, "This really isn't a volcano story." The giant magma chamber under the park could cause worldwide devastation if it erupted, but the release of gases does not indicate this being an imminent danger. The geysers for which Yellowstone is famous have been erupting since before the area's discovery by explorers in 1809, and for the same reason as the helium degassing: heat from magma. As for the latter group, Yellowstone is a protected national park, and extracting helium would not be economically viable.

An important distinction to make about the gas release is that "recent" refers to the geological timescale. Helium has been coming out of Yellowstone's geysers for two million

years. What is notable is that the radioactive helium-4, formed by the decay of uranium, is leaving the crust hundreds of times faster than it is formed, on the order of 60 tons per year. Given that Yellowstone is one of the oldest areas of continental crustal rock in the world, this helium may have formed billions of years ago and been trapped underground ever since.

Why is it being released? The current theory is that the movement of the volcanic hotspot under the crust caused the release through rock metamorphism: volcanic heat turned sedimentary stone into metamorphic rock, warping it in the process and giving the helium a channel to the surface. Coauthor Bill Evans attempted to put this process in simple terms: "Think of it this way: You have these old crustal rocks just sitting around for hundreds of millions, perhaps billions of years...They have this boring little existence, and then suddenly somebody puts the heat on under them and they start giving up all their long-held secrets." The release of helium at Yellowstone is not something the public needs to worry about, but hopefully it will present geologists with an abundance of data on dynamic earth processes. ■

SLEEPING AROUND THE CLOCK

How Gene Expression Regulates Speech

BY JEN OBRIGEWITCH, BIOLOGY, 2017

The average American spends 234,000 hours, 9,733 days, or 27 years sleeping.

For most people, sleep is a thoughtless task. The human body makes sleep seem simple; there are some people that can fall asleep anytime, anywhere, no matter the surrounding noise. Yet there are many factors that affect a person's sleep, and recent research has delved into how exactly sleep is regulated by the body and the brain.

Areas in the brainstem, hypothalamus, and cerebral cortex control wakefulness, depending on the messages sent by neurotransmitters such as adenosine, which gradually builds up during waking and inhibits wake-promoting neurons. These neurotransmitters and other messages that are released are largely regulated by the homeostatic sleep drive and by circadian rhythms. The homeostatic sleep drive inspires sleepiness when the body has slept little and insights wakefulness when the body is well rested. Circadian rhythms are body processes synced to a steady 24-hour day and night cycle by the body's internal pacemaker. Day and night also affect the body's state of consciousness because light signals from the eye stimulate the body's biological clock, promoting wakefulness during the day and sleepiness at night.

“We spend a third of our lives sleeping.”

Though the human body has a large number of universal methods to help regulate sleep, specific sleep patterns exist that vary from individual to individual. The circadian rhythms of a human can run at different speeds, causing the 24-hour cycle to differ in length. This causes the “morning bird” and “night owl” phenomena; “morning birds” seem to have circadian rhythm cycles that run slightly faster than that of the “night owls.” This variation in the circadian rhythms is caused by genetic variation in the person’s DNA sequences.

A recent study at the University of Surrey in the UK showed that when participants were kept in an environment that created a 28-hour day, their sleep-wake cycles were disrupted enough that they began to sleep during what

should have been mid-day. While their bodies were in this disrupted pattern, blood samples were collected from participants. The rhythms of gene expression were found to have been altered; the researchers found that six times as few genes displayed a 24-hour circadian rhythm. These genes were not only related to sleep, but also to other important biological processes. This study showed which genes are regulated by sleeping cycles and which are regulated by internal body clocks. This study proved that sleep affects many more biological processes than previously believed. Once the relationship between sleep and other processes has been studied, researchers will be able to determine how to use sleep in order to maximize the body’s efficiencies at these other processes. This study and the research stemming from it continues to show just how important the sleep cycle is to the body’s rhythm and its important biological functions. If altering sleep can change how the body regulates transcription and translation, will a change in sleeping patterns become the new antidote for diseases that involve abnormal regulatory patterns?

Looking at all of this information, it is natural to wonder what each person can do to maximize his or her wakefulness and sleep quality. Sensing what your body is telling you it would like to do is key. If you are tired, your body is craving sleep. Know what activities will negatively affect your sleep quality and what will help. Keep your schedule as consistent as possible; studies have shown that taking naps, changing time zones, and working at odd hours will offset almost a third of your body’s processes and impact circadian rhythms and other biological cycles. Gene expression can actually be thrown off rhythm so much that it does not display a 24-hour pattern at all, but rather something of a different length.

We spend a third of our lives sleeping and many of us spend the other two thirds thinking about how we wish we could have slept longer. Sleep may seem like such a simple task, but it can have a strong effect on nearly every aspect of life. Keeping the body in rhythm will maximize its functionality in other areas, from academics, to sports, to social interactions. Why lose sleep worrying about those things, when you can just sleep to improve them? ■



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