

# NUScience

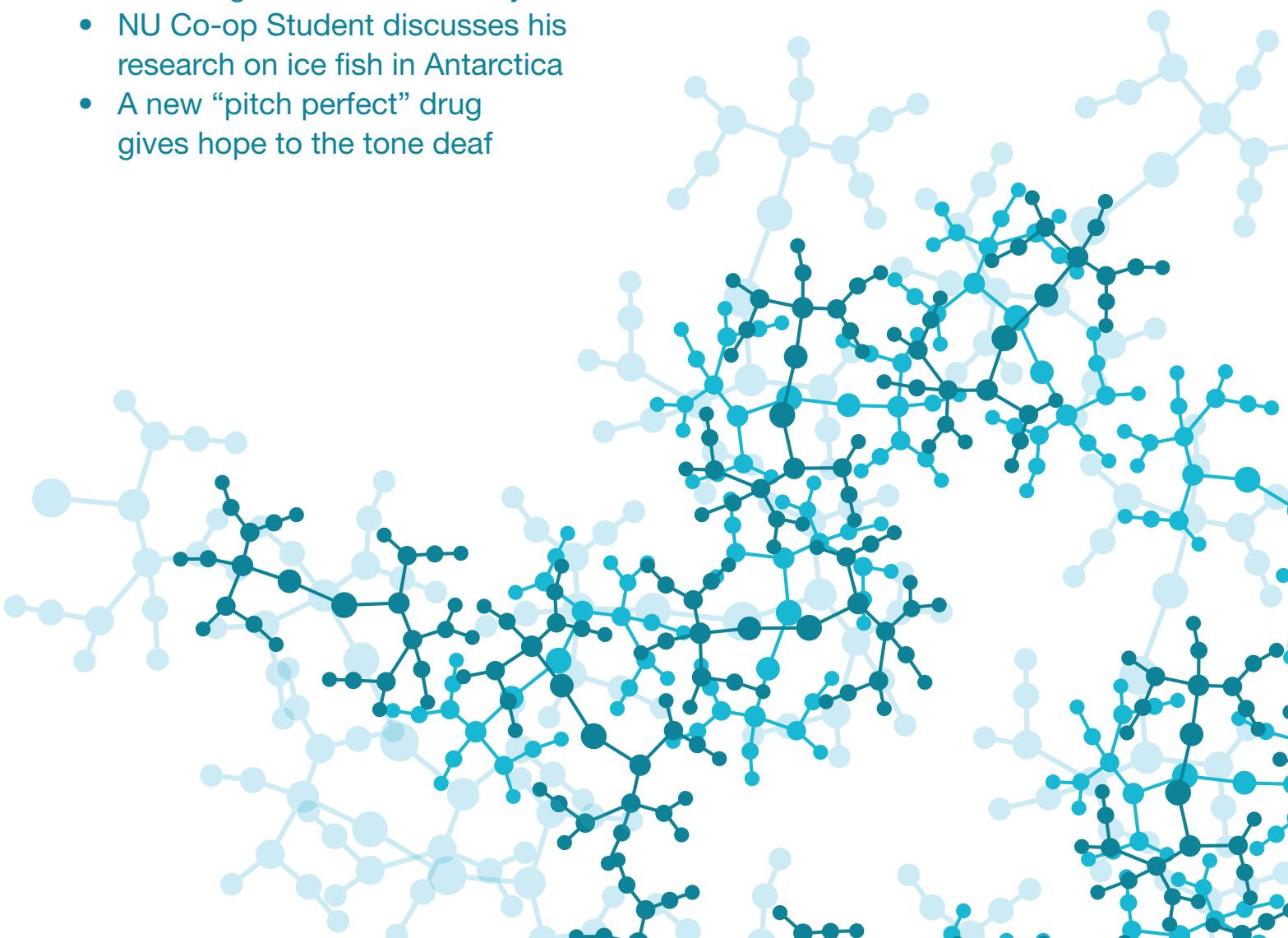
Science by Students: Northeastern University

## Treating Disease at the Source

How gene therapy is making a resurgence as a cure for genetic diseases

### Also Inside:

- Bond-style “rebreather” could make breathing underwater a reality
- NU Co-op Student discusses his research on ice fish in Antarctica
- A new “pitch perfect” drug gives hope to the tone deaf



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## GET INVOLVED!

Are you looking for a creative way to showcase your work on campus? Do you want to boost your resume in a way that's creative, intellectual and fun? Become a part of 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,

In the world of science, researchers are constantly out searching for ways to better understand our world and to ultimately improve it. One of the best ways to improve the quality of life on Earth is by making advances in medicine and by creating new drugs and treatments for ailments of all kinds. There are over 160,000 clinical trials occurring around the globe, and every day new products and treatments come along that could improve or save lives. From new and revolutionary gene therapy treatments, to drugs that have gone out of style, this issue of NUScience Magazine explores the fast-paced world of drug and treatment discovery to show you the history, process, and just some of the amazing results.

I'm also proud of the amazing results that our writers, editors, and designers have achieved for Issue 18, and I honestly feel that each issue is better than the last. This issue will also be one of the last that I serve as co-editor-in-chief for, as we begin transitioning our rising E-board members into their new leadership roles. I am confident that NUScience will be in good hands with the next generation, and that their curiosity, creativity, and love of science will continue to bring NUScience to the next level: issue after issue.

In addition to drug discovery, this issue features some unique findings about marine life (big and small), interviews with members of the Northeastern community, and several articles that are out of this world. Scientists around the world are out looking for the cures to everything, but if you're looking for a cure for boredom, curiosity, or a long T ride home, it's here in these pages. You'll be sure to learn something new.

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

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- 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

## Upcoming Northeastern Events

### Inferring Population Dynamics and Local Adaptation from Genetic Data

Marine Science Center, Trailer Classroom, 430 Nahant Rd., Nahant

March 11, 2014 at 4 p.m.

Dr. Katie Lotterhos of Wake Forest University will speak in the regular Nahant colloquium series as a guest of Dr. Randall Hughes.

### Global Health Seminar – James Aggen

206 Egan, Northeastern University, Boston

March 21, 2014 at 2 p.m.

Professor James Aggen of Northeastern's Chemistry and Chemical Biology Department will discuss the need for new antibacterials to counter multi-drug resistance.

### Barnett Lectureship “Development of Disease Diagnostics by Discovery Mass Spectrometry”

Raytheon Amphitheater, Egan Research Center, Northeastern University, Boston

March 25, 2014 at 4 p.m.

Professor Vicki Wysocki from Ohio State University will speak on developing diagnostics in a new way.

# Biomimicry: Learning From Nature

BY ANKIT DANGI, CS GRADUATE STUDENT, 2015

Man's every discovery, invention, and creation has revolved around nature: man an artist's source of inspiration, a scientist's postulation of observable natural phenomenon, an industrialist's manufacturing capacity depending upon consumption of natural resources, and others, have all designated nature as the de facto source of cross-functional imitation. Formally, imitation is the replication of actions upon observation; in practice, it is one of the foremost tools for learnability from tried and tested phenomena.

Throughout existence, humans have looked to nature for answers to complex problems. While Newton had the apple to gravity story that elicited the *Universal Law of Gravitation*, other significant inspirations with thin-lined imitations include understanding how birds fly to enable first human flight, seed dispersion of Burdock burrs/seeds towards the conceptualization of Velcro, echolocation modeling in Bats in darkness leading to design of canes for the visually impaired, and the ability of spiders to create web silk inspiring the Kevlar used in bulletproof vests. While learning about the natural world is one thing, learning from nature encompasses the core principles underlying the science of biomimicry. It is about imitation-based learning from models, systems, and elements of nature for solving both complex and simple human problems. Traditionally, a similar field known as biomimetics has been the study of structure and function of biological systems as models for design and engineering of modern-day materials and machines.

Biomimicry was popularized by scientist and author Janine Benyus in her 1997 book *Biomimicry: Innovation Inspired by Nature* and TED talks in 2007 and 2009. Benyus suggests looking to nature as a "model, measure, and mentor" and emphasizes sustainability as an objective of biomimicry. In her TED talks, she mentions that while humans make materials by the "heat, beat and treat" principle, leaving aside a large percentage as waste, nature and life makes things by adding structural and functional information to matter. She mentions that life does not distinguish things from systems in the natural world; rather, they don't appear as distinct entities and are coherently well-formed elements of nature and life.

Some successful biomimicry ideas and principles include self-assembly based automated recoding processes at lower temperatures for layered structure in ceramics, carbon dioxide as feedstock for biodegradable



Otto Lilienthal's 1894 ornithopter mimicked the flight of a bird with flapping wings. Photo courtesy of Wiki Commons.

plastics, and the development of fuel cells without platinum by evolving hydrogens from protons and electrons to mimic solar transformations. Other applications of biomimicry draw on animal science, such as structurally imitating whale and dolphin flippers to model wings of modern-day passenger aircrafts and fighter planes, and inducing color without pigmentation based on scatter of light across shapes of an element using thin-film interference, as in peacocks and butterflies.

Biomimicry can also draw from the natural world. Real-world applications include elements that self-clean with water and no detergents, like how lotus leaves clean themselves while blooming from muddy water; mining metals from oceans without mining/drilling, but by separation techniques similar to that of microbe molecules; timing packaging degradation by containing the packaged material only until required and dissolving on cue; and addressing the problem of vaccines unable to reach patients due to lack of refrigeration along the chain of supply by encapsulating them in gloved sugar compartments as tardigrades, or waterbears, regenerate themselves after re-hydration.

Learning from organisms and fundamental substances shapes the principles of biomimicry. There are millions of life's genius evolutionary adaptations that other organisms have drawn on since the onset of time. Arguably unlike human species, these organisms take care of

the places that shall take care of their offspring. They preserve nature by creating opportunities for life to address longer sustainability. Life's design is simple, and has worked over billions of years since life evolved on the planet. By creating conditions that are conducive for life: soil, water, air, cocktails of enormous chemical elements, corrections of every anomaly that does not favor life-advancing conditions have been phased out. Darwin's natural selection or Spencer's survival of the fittest, intended to mean better designed for an immediate, local environment, relate to nature's principles that reflect over longer sustainability. Organisms that have failed to create conducive environments for further life have become extinct.

The field of computer science and modern-day data science have built large-scale algorithms for massive parallel computations based on similar evolutionary methods inspired by biological evolution under the umbrella of evolutionary computation. Learning from these biological fundamentals, events, and principles to solve complex human challenges led to the envisioning of the art and science of biomimicry. ■

# Measuring the Universe:

Scientists are able to measure the distance between galaxies with incredible accuracy

BY SUMAYAH RAHMAN, BIOLOGY, 2015

**A**t the 223rd meeting of the American Astronomical Society, researchers from the Baryon Oscillation Spectroscopic Survey (BOSS) presented some astounding findings: they were able to measure the distance between galaxies in the universe within an accuracy of 1 percent. These new, highly accurate measurements go more than a million times further than our galactic boundaries, and have measured the distance to galaxies over 6 billion light years away.

The researchers were able to do this so accurately by measuring baryon acoustic oscillations (BAOs), which are the imprints of pressure waves that once traversed through the early universe. These BAOs, which helped set the current distribution of galaxies, work very

well as a standard ruler to measure distances because galaxies tend to line themselves along the edges of these ripple-shaped waves.

In astronomy, determining distance is usually a difficult task—yet it is one that is vital to the study of celestial bodies. “Once you know how far away it is, learning everything else about it is suddenly much easier,” said Daniel Eisenstein, director of the Sloan Digital Sky Survey III, the worldwide organization that includes BOSS. Although it may seem that the distance of these far-away galaxies have little significance to us on planet Earth, it turns out that the results of this study have some much deeper implications. These findings suggest that the amount of dark energy, the force believed to have caused the universe to expand so quickly, has been constant

since the universe began, supporting Albert Einstein’s theory of a cosmological constant. The cosmological constant is one of six numbers that is needed to define the structure of the universe. The results from the BOSS study help us understand the curvature of space—and according to these findings, the universe is quite flat. The idea of a flat universe supports the theory of an infinite universe, since it can extend forever in space.

BOSS has mapped over a million galaxies, but there are still large gaps between the boundaries defined by the research team. The next steps for astronomers will be to use nature’s ruler to fill in these gaps and to explore even further into the depths of the universe. ■

# Europa: The Search for Little Green Men

BY GABE PLAYER, PHYSICS, 2018

**T**he search for extraterrestrial life has long resided solely in our imaginations—in books, movies, radio broadcasts, and popular culture. Until the space race of the late 20th century, actually finding “little green men” was nothing more than a dream. However, with the advent of spacefaring probes, telescopes, and robots, the dream of finding extraterrestrial life may finally become a reality.

In particular, the Hubble Telescope’s recent discovery of water spouting from a rift on the surface of Europa could be possible evidence of extraterrestrial life. On Dec. 12, NASA scientists announced that a geyser of water nearly 125 miles high had been spotted emerging from the southern polar region of Europa.

Scientists have long theorized that Europa could harbor some form of extraterrestrial life; its surface is composed mostly of ice, and it is thought to have a subsurface ocean. The implications of a subsurface ocean are extensive—primarily, though, the presence of a protected hydrosphere could allow for the development of organic compounds, and

possibly even extraterrestrial life. The possible existence of this inner hydrosphere has moved a long way towards confirmation with the sighting of the geyser, and hopes are high for NASA’s ability to probe for more data. According to the head of NASA’s planetary science division, Jim Green, “The plumes are incredibly exciting, if indeed they are there. They’re bringing up material from within the ocean; perhaps there’s organic material that will be laying on the surface of the south pole.”

The discovery of the geyser has also reinvigorated interest in a NASA program called the Europa Clipper, a probe that was proposed, but not formally accepted, in 2012. With this new data from Hubble, the hope is that NASA will take another look at the Europa Clipper. Should the mission be accepted, the Clipper would be tasked with retrieving information about the composition of the subsurface ocean, so scientists could make a better approximation of its potential habitability.

Before the discovery of the polar geyser, the proposal for the Europa Clipper mission

revolved primarily around flyby scans of the moon’s surface to determine the thickness of the ice, with the hope of future drilling missions to the surface of the moon. With recent events, the new proposal in development may include sample collection from the geyser. Kevin Hand, a NASA planetary scientist, is currently working on a plan that involves the Clipper probe doing at least 32 flybys of the plume, collecting samples each time. “We need to get a spacecraft back out to this fascinating world to better explore and understand its potentially habitable ocean,” Hand said of the project.

Whatever the fate of the Europa Clipper, the emergence of the geyser of water from its south pole has put NASA a lot closer to understanding the second moon of Jupiter and is another step forward in the search for extraterrestrial life. ■



# NEW HYPERVELOCITY STARS SET HEARTS AND MINDS RACING

BY EMILY ASHBOLT, BIOMEDICAL PHYSICS, 2017

The Milky Way, the 100,000 light year-wide galaxy that is home to Earth, is something that most people take for granted. Everything that they know is located here, and they can't exactly leave; escaping the relatively small galaxy is rather challenging. This is because the required velocity to do so is so massive. It's hard to even comprehend a way that anything could reach it.

But some things can.

There are giant blue stars that scientists have recorded that reach speeds of up to 1.6 million kilometers per hour: enough to pop out of the edge of the Milky Way and into the ether beyond.

Only 18 stars like this have ever been documented. Eighteen stars might not sound like very many—because it's not. There are approximately 300 billion stars in the Milky Way. So of the 300 billion stars popping and buzzing above, only 18 have ever been seen to escape. How did they do it?

One way to unravel the mystery of the stars' great velocity is by tracing their trajectories backwards to try and see where they started. From the paths that scientists have managed to track, they deduced that the stars pick up their speed somewhere in the galactic center. There are two main theories as for how, both involving binary star systems. Binary star systems are much more common throughout the galaxy than our single-sun Solar System. These systems are the cornerstone of the blue giant hypervelocity star theories due to the gravitational properties of a system that depends on more than one massive object.

One theory proposes that hypervelocity stars get their velocity when a binary star system gets too close to the supermassive black hole (known as SgrA\*) at the center of the Milky Way galaxy. When this occurs, one star may be captured while the sudden jolt projects the other star away. The second theory pairs a binary star system with a supernova, a massive galactic event in which the center of a star collapses and expels stellar material at enormous speeds. Scientists believe that if one star in a binary system exploded, it could cause a large enough disruption to shoot the remaining star off on its biggest adventure yet.

These are by no means perfect explanations, as the laws that govern the orbits of massive celestial bodies involve a great number of variables. Theory two particularly comes into

question given that no supernovae have been recorded in the Milky Way for over 400 years. But for the most part, these theories have made sense and have been supported by statistical analysis—until now.

At the start of the year, graduate student Lauren Palladino of Vanderbilt University published research in the *Astrophysical Journal* about her discovery of new hypervelocity stars. The new stars are yellow dwarfs, much smaller than the previously discovered hyperfast blue giants; most are about the size of our sun. These stars are causing a stir across the astrophysics community due to their trajectories, which suggest an origin other than the galactic core.

Palladino, along with her team, has identified about 20 of these stars moving at the speeds necessary to break out of the Milky Way's gravitational grip. While blue giants have proved that such events are possible, none of the previously escaping stars came from somewhere other than the fertile center of our galaxy.

Palladino presented her findings at the 223rd Meeting of the American Astronomical Society, and the theories as to where these stars may have acquired their speediness have come thick and fast with the new evidence. There has been talk in the scientific community of interactions with dwarf galaxies and globular clusters, mentions of gravity assist, and even some theories that these stars belong to another galaxy and are merely meandering through ours on a casual galactic hike.

Palladino offered little explanation for the actual creation of the stars, admitting that confirming the calculations of their particular trajectories will take many decades of careful observation to understand. Still, the evidence that these high-speed stars exist in a different form, and may have different origins than their large, blue counterparts is sure to lead to new theories and observations from astrophysicists around the world. As the research progresses on this new mystery, all eyes will be on the sky. ■



# A Safer Medical Marijuana Treatment

## On the Horizon

BY JUSTINE BELINSKY, BIOLOGY, 2018



**M**edical marijuana: a revolutionary treatment for modern illnesses, or a dangerous drug with more risks than benefits? This controversial treatment was the main focus of a new study by Dr. Monique Vallee and colleagues, which found evidence that there may be a safer and healthier form of medicinal marijuana. The study, published in January 2014, is important for the future of novel drugs for patients experiencing a wide range of ailments, such as arthritis, eating conditions, and seizures.

*Cannabis sativa*, more commonly known as marijuana, is reported to be used by 20 percent of young people at least once a week. Marijuana use during adolescence can lead to severe effects on brain development that can persist even after usage has terminated. For example, depression, schizophrenia, and other psychotic disorders are more common in people that used marijuana from a young age. In a study in Dunedin, New Zealand, researchers observed the strongest negative effects in subjects who began using before the age of 16. Early use of marijuana can lead to addiction, but Vallee's study may lead to drugs that could help addicts break the habit.

The benefits and risks of medical marijuana have been debated for many years, and will continue for many more. However, it is clear that there is a social stigma associated with marijuana: in a 2013 survey of the Colorado Academy of Family Physicians, 46 percent of respondents said they would not recommend marijuana as a medical therapy. Additionally, more than 60 percent said that there are physical and mental health risks with marijuana. In 2006, the Drug Enforcement Administration said that smoking marijuana presents just as many health issues as smoking cigarettes, with four times as much tar in marijuana. Furthermore, regulating dosage in smoking is very difficult, making medicine delivery more problematic than conventional drugs.

Despite numerous health risks, there are also many ways that marijuana can be beneficial, and some doctors very often prescribe medical

marijuana as a way to ease suffering. For example, marijuana can help a wide range of conditions, such as Alzheimer's, HIV, AIDS, multiple sclerosis, cancer, and Crohn's disease. Furthermore, it can help reduce the pain, restore appetite, and even ease menstrual cramps. Because of its many medical benefits, Dr. Lester Grinspoon, a professor of psychiatry at Harvard Medical School, wrote that if marijuana was discovered clinically before it was used recreationally, "it would be hailed as a wonder drug." Still, in a 2003 study, many doctors said that they would only recommend marijuana for patients that have terminal illnesses. Overall, less than 30 percent of physicians said that there are significant health benefits associated with marijuana.

The 2013 study by Vallee and her team discovered a negative feedback loop involved with cannabis use that could help people become less dependent on cannabis. The process involves the steroid hormone pregnenolone and tetrahydrocannabinol (THC), the active chemical in cannabis. Pregnenolone is a neurosteroid, meaning it is a steroid that is produced in the brain; it helps regulate mood, and is important for cognitive memory. Additionally, pregnenolone is the precursor of other steroids, such as progesterone, testosterone, estrogen, and cortisol.

In this experiment, researchers injected rats and mice with strong drugs, including cocaine, morphine, nicotine, alcohol, and the main active ingredient of marijuana, THC. Observed effects of THC were similar to that of marijuana, such as increased appetite (commonly known as the "munchies") and decreased memory performance. However, in mice that were also injected with pregnenolone, the researchers saw a significant decrease in THC-induced food intake and memory impairment. Additionally, THC alone caused an increase of dopamine levels and firing activity of neurons, but mice pretreated with pregnenolone essentially stopped exhibiting these effects.

Mice were also tested using an intravenous

self-administration model, where they chose between two devices, one that injected the drug (the active device) and one that did not (the inactive device). Overall, the mice showed a preference for the active device, except when the mice were injected with pregnenolone before the experiment. From this, researchers concluded that there is potential for pregnenolone to reduce cannabis dependency in users.

The researchers also discovered that only pregnenolone, and not its downstream-derived neurosteroids, will inhibit the negative effects of THC. For example, allopregnanolone was not able to modify and behavior changes due to THC. Additionally, as an allosteric modulator (which binds to a site distant from the active site), pregnenolone can be signaling-specific, meaning it regulates only some functions of the receptor. Such allosteric modulators can be more helpful than orthosteric antagonists (which bind at the primary site of a ligand), which very often produce discomfort in patients. Furthermore, pregnenolone cannot be overcome by increased drug intake the way that orthosteric agents would.

Given the recent fight for decriminalization and medical and recreational legalization of marijuana in the United States, the debate over the safety of the drug will continue for many years. There are many health and social risks of marijuana, but it can also be used to medicinally ease pain and suffering. As the country's population continues to age and people live longer, they will seek out pain relief more and more, and medical marijuana may be the answer. From the discoveries of this study, more research will most likely follow to find drugs that draw out cannabis' most beneficial aspects while eliminating its worst psychoactive effects. ■

# Maestro Medicine: The Pill for Perfect Pitch

BY MATTHEW DEL MASTRO, BIOLOGY, 2017

Those closest to the great composer Mozart often marveled at his incredible ability to name musical notes produced not only by instruments, but by any of the myriad noises that surrounded him. Mozart recognized if a church bell tolled a C or if his watch alarm sounded a B flat. The possession of absolute pitch, the ability to pick out the pitch of a single note without a reference, has long been thought of as a gift bestowed to a select few individuals, such as the prodigious Mozart. A new study challenges this perspective by suggesting that someday, taking a pill may allow even the least musically gifted person to develop an ear to rival Mozart's.

The pill that would give hope to the musically inept is valproate (VPA), a mood stabilizer often used to treat bipolar disorder. Valproate has been associated with an increase in neuroplasticity, the brain's ability to form new neuronal connections and pathways that facilitate learning and memory. Neuroplasticity is typically greatest during certain early developmental stages, termed "critical periods," before fading to lower levels later in life. The heightened neuroplasticity levels present during youth explain why it is often easier for children to learn new languages, take up new sports, or even develop perfect pitch.

Takao Hensch, a researcher at Harvard University, decided to test whether VPA's effects on neuroplasticity could reopen closed critical periods and enable the development of perfect pitch in adults. He and his colleagues recruited 24 adult males, each receiving a daily dose of either VPA or a placebo, and trained them to associate six pitches with six different names. The study used proper names such as Karen, David, and Leo as opposed to the names of the actual musical notes in order to level the playing field between those with prior knowledge of music theory and those without it.

After completing the training, each subject underwent a test of his pitch identification skills. The participants were asked to match 18 notes with the related proper name. The men taking the placebo were only able to identify 3.50 notes correctly, a result no better than what they could have guessed randomly. On the other hand, the men treated with VPA averaged 5.09 correct answers, a result significantly better than chance. While an average score of 28 percent correct hardly seems to place the VPA-taking men on par with Mozart, the achievement becomes more impressive when one considers that the study was performed with candidates having little to no musical background over a very short time period. There has never before been a recorded

improvement in absolute pitch under these two conditions. Given the circumstances, even such a small improvement in pitch identification demonstrates the powerful potential of using a drug to stimulate neuroplasticity and reopen critical periods.

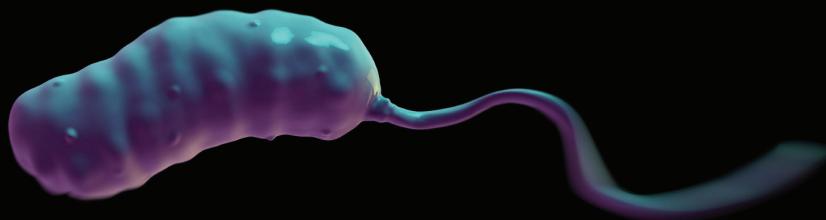
**"We're not opening the brain up to a massive rewrite. We're enhancing its potential for plasticity – which, when paired with training, can manifest in changes we want."**

Although the study was significant as evidence of the principle that drugs can enhance human neuroplasticity, there are still many questions researchers must explore before the average man can distinguish the notes of his cell phone ring tone. First, the researchers did not examine the duration of the improved pitch facilitated by VPA. It would be unfavorable to continuously use the pill to maintain perfect pitch if one also had to tolerate the pill's side effects, which include weight gain, fatigue, and depression or irritability.

Perhaps the most important question of all is if neuroplasticity can be so beneficial, why does the brain shut down critical periods at all? One possibility is that continuous and widespread changes to the brain's connective network could be highly destructive. Neuronal connections might be formed or lost at the wrong times, with disastrous consequences. There is some evidence to suggest that autism may be due in part to malfunctioning critical periods. However, Hensch has downplayed VPA's potential to cause this type of damage. He notes that the drug has already been approved as a treatment for bipolar disorder and epilepsy, and he claims that the drug does not have a scope wide enough to trigger detrimental consequences.

Hensch explained to *New Scientist*, "We're not opening the brain up to a massive rewrite. We're enhancing its potential for plasticity – which, when paired with training, can manifest in changes we want." Despite this, would-be Mozarts would be wise to await further research to ensure that they don't knock their brains out of rhythm in search for the perfect pitch. ■





# Progress In The Time Of Cholera

## Mcmaster's Lab Decodes Circa-1800 Cholera Strain

BY LOLA AKINGBADE, BEHAVIORAL NEUROSCIENCE, 2018

Until now, the pathological and genomic origin of cholera has remained a mystery among the scientific community. However, researchers at McMaster University's Ancient DNA Center in Canada have recently identified the strain of bacteria responsible for cholera's 19th century outbreak.

Cholera is a diarrheal infection caused by consumption of contaminated food or water which leads to dehydration, vomiting, and often times death. McMaster's and colleagues analyzed first strains of bacterium *Vibrio cholerae*, the cholera bacterium, through collaboration with American colleagues and a resource from the Museum of the History of Medicine in Philadelphia: a small, well preserved intestine sample from an 1849 victim of the disease. The sample is particularly rare, given that the cholera bacterium thrives in the gastrointestinal system, which decays quickly following death. The process of decoding the

complex genome was made possible through the museum's maintained specimens.

The work, published recently in the *New England Journal of Medicine*, determined that the second largest cholera outbreak in the 1800s was not caused by today's most notorious strain, called "El Tor." Instead, researchers concluded that the classic cholera strain was most likely the cause of the second historical cholera outbreak.

This is not the Ancient DNA Center's first notable feat in genomic coding and pathology. In 2011, the lab was involved in recovering the DNA of the bubonic plague pathogen *Yersinia pestis* from skeletal teeth in a 13th century London graveyard.

Cholera, a disease responsible for multiple epidemics which continues to claim lives in some of the poorest regions of the world, soon became the lab's focus. Sequencing the 1894 classical strain revealed similarities in genomic base-pair

groups to contemporary strains. The scientists argue that the absence of three major genomic "islands," or gene regions, in the classical strain, which are present in modern El Tor, explains its decline after the 19th century.

"The genomes of ancestral pathogens that have descendants today reside in these archival medical collections all over the world. We have access to hundreds of thousands of ancient specimens, which hold tremendous potential to determine the origins of past epidemics," said Hendrik Poinar, an evolutionary geneticist, professor, and director of the Ancient DNA center.

With preserved specimens as a resource, Poinar and his team look to expand the scope of evolutionary and historically based genomic research of diseases such as cholera. With their work, advancing disease prevention and treatment options for cholera and other diseases is becoming possible. ■

# Sharks Can Get Cancer and May Help Us Cure It

BY JOSHUA COLLS, BIOLOGY, 2016

The shark species as a whole has been alleged to contain a natural tumor suppressing method embedded into the fibers of their cartilage. However, that cancer-free claim has been debunked by a photograph, taken during a recent shark sighting, that clearly depicts a rather large tumor on the lower jaw of a great white shark. Take that, Mythbusters!

The number of sharks with documented cancer has slowly increased over the last 150 years to include upwards of 40 types of cancer. This increase can be attributed to water pollution caused by humans. Given this rise in water pollution, sharks are now more prone to developing cancer from the consumption of toxic livers of fish that reside in polluted waters.

Even with this evidence and knowledge, the preconceived notion that sharks do not get cancer still subsists. Today, sharks are very sought after based on the notion that their cartilage contains curative powers. This assumption spurred a rather dramatic and detrimental hunt for sharks. Discernibly, the only way to obtain shark cartilage,

and uphold the current demand, is relentless fishing. It has been exploited so vigorously that around 100 million sharks are caught annually. Some of these sharks are harvested for medical curative products that claim to cure cancer, but often provide less of a cure in its popular capsule form than people seem to think.

With that being said, the cartilage of a shark does have potential in the cancer treatment field, however it is probably ineffective in the capsule form in which they are currently being sold. Impressively, this non-bony tissue has been effective in treating Kaposi's sarcoma, which is a type of cancer more commonly found in patients that possess HIV. Also, this cartilage may hold medicinal value for anomalies such as arthritis, psoriasis, wound healing, and retinal damage.

The reasoning behind these medical successes lies in the cartilaginous tissue impeding blood vessels from tumor propagation; without blood flow the growths tend to wither and become nonthreatening. This realization stands as a major breakthrough in cancer

treatment, as malignant metastization can be barred through prevention of angiogenesis, or the anatomical process by which blood vessels augment through other blood vessels, and capillary growth.

Cancer, although referred to singularly, has a myriad of different forms and natures, and the properties of tumor suppression that are held in cartilaginous fish and sharks may be widely applicable in cancer treatments. To only offer a remedy in pill form without further research into these properties seems to undermine its potential healing implications.

Given this experimental outlook, the clear evidence of a tumor in a shark has resulted in more questions than answers as to the benefits and healing abilities the shark cartilage is thought to possess. This is now "a thorn in the side" of marine biologists and oncologists, as the trek to understand the true usefulness of cartilage continues with a bit of a hiccup from this discovery. ■

# Deep-Sea Bacteria Secrete Vesicles Containing Vital Compounds

*Wasting precious nutrients, or ensuring their survival?*

BY ADANYA LUSTIG, UNDECLARED, 2018

In a recent study at MIT, researchers have found that deep-sea bacteria are secreting vesicles containing DNA, protein, and calcium. All bacteria are known to release vesicles as a normal process during growth, but they do not usually contain these vital substances. There is much speculation as to why they do this, but no one has a definite answer. However, this research team has confirmed the contents of these vesicles and begun to hypothesize about their purpose.

"The vesicles are a previously unrecognized component of marine ecosystems and we think that they are probably playing an important role in mediating interactions among bacteria and their environment," said Steven Biller, head of the research team, in a podcast interview posted on the *Science Magazine* website.

The marine cyanobacteria *Prochlorococcus* and *Synechococcus* are the most frequently occurring producers in parts of the sea with few nutrients, like the deep sea. *Prochlorococcus* has been shown to secrete vesicles at a global rate of 1027 to 1028 vesicle per day, with about two to five vesicles per cell division.

"Together these cells with this huge population size carry out roughly, something on the order of 10 percent of all global photosynthesis," said Biller. "They're taking sunlight and carbon dioxide and making organic carbon."

The *Prochlorococcus* vesicles contained many proteins, although the researchers do not know if they are bioactive like the active enzymes found in vesicles from other bacteria. Perhaps most exciting is the DNA found in these vesicles—when researchers analyzed the vesicles, they found enough DNA fragments to encode multiple genes. The sequences revealed that it covered over 50% of the chromosomal sequence, but there were more fragments around the terminus region.

"*Prochlorococcus* is releasing little snippets of its DNA from all across its genome within these

vesicles and it's really kind of a mystery as to what that's for and how that's happening," said Biller.

The vesicles were prevalent in nearby Vineyard Sound, MA and in the Sargasso Sea near Bermuda, in a similar ratio to the prevalence of the bacteria, further reinforcing that these vesicles do come from the bacteria.

*Prochlorococcus* has previously been found to be responsible for a large amount of the carbon in parts of the ocean lacking in

**“When researchers analyzed the vesicles, they found enough DNA fragments to encode multiple genes.”**

nutrients, supplying organic compounds to marine heterotrophic bacteria. Biller and his team proposed that this carbon may be coming largely from the vesicles. To figure out if this is true, they studied two other kinds of bacteria and found that they could survive in a laboratory setting even if the only carbon source was from *Prochlorococcus* vesicles. *Prochlorococcus* are known to thrive when surrounded by other heterotrophs, so this contribution to the neighbors could be a selfish one.

"We know that *Prochlorococcus* grows better when it's actually around other heterotrophic bacteria because they turn out to rely on a lot of these other bacteria to help them get rid of things like reactive toxic oxygen species," said Biller. "One of the ideas is that maybe releasing some of this carbon could help facilitate this, so if you have enough carbon around you're sort of encouraging the other bacteria to be around you, farming your own helpers out."

What's strange is why in the world these bacteria are excreting their precious resources when they live in such harsh environments.

"This was really one of the most surprising aspects of these findings to us because we know that *Prochlorococcus* has evolved a number of different adaptations to grow in very low nutrient conditions," said Biller. "They have a tiny cell size and they have a really small and streamlined genome, so everything to this point has been telling us that they're really conserving all of their precious nutrients, but now we're seeing that they're just getting rid of them pretty continuously."

Another selfish explanation is that the vesicles protect the bacteria from viruses, known as phage. If this explanation is true, it gives the bacteria better odds of not getting infected—the cyanophage mistakenly infect the vesicles instead of the bacteria. The researchers tested this hypothesis and found that when they combined purified *Prochlorococcus* vesicles with phage known to attack that strain of *Prochlorococcus*, the phage did appear to have injected their DNA into the vesicles, attempting to infect them.

The DNA that *Prochlorococcus* secretes into its own vesicles is especially fascinating and mind-boggling. When the researchers studied a large number of random vesicles they found DNA from members of 33 phyla, suggesting that the DNA in the vesicles is implicated in horizontal gene transfer. This supports that the vesicles are somehow bridging the gap between diverse marine microbes, which might not otherwise be possible.

These discoveries begin to illuminate the deep sea, but they are only the first of many necessary for fully understanding the complexity of microbial marine life. Further studies to test the various hypotheses on the purpose of the vesicles will be crucial in moving forward with research. ■

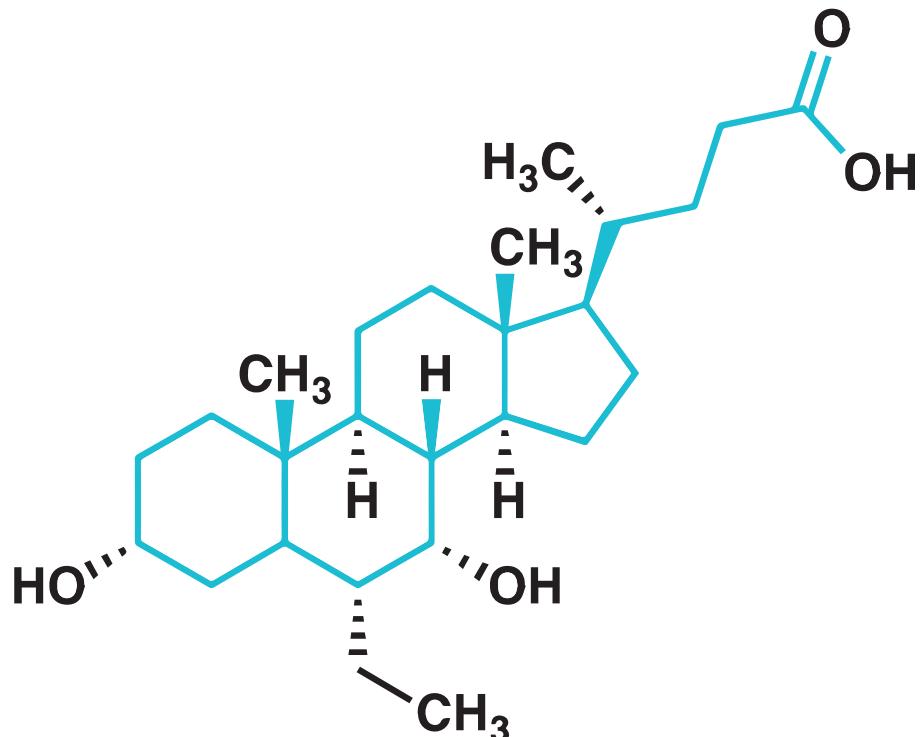
# Fast Tracking Drug Approval

BY POOJA NAGARAJAN, DRUG REGULATORY AFFAIRS GRADUATE STUDENT, 2015

With the advent of an era of clinical trials and human experimentation, and the nature of these protracted studies, fast tracking or expedited approval of drugs and related products seems to be an emerging trend. The multifaceted process of drug development usually takes 10 to 15 years on an average, with enormous capital investment. Only one out of every 10,000 discovered compounds becomes an approved drug for sale. Expenses incurred in the early phases of development are tremendous and most of the time it is only money down the drain when they are not approved for marketing. This means that for a drug company to survive, it needs to discover a blockbuster (billion-dollar drug) every few years.

This would best be exemplified by a recent episode, where a company, Intercept Pharmaceuticals Inc., rose to glory because of its successful clinical trials for the drug obeticholic acid, or OCA, intended for use in a rare disease called non-alcoholic steatohepatitis (NASH). In this disease, the people who don't drink or drink very little alcohol suffer liver damage that resembles that of heavy drinkers, which ultimately affects the organ's functioning. The root cause of this disease is not known, but it is mostly observed in people with obesity or diabetes.

This drug was primarily intended for the treatment of biliary cirrhosis, an autoimmune disease in which bile ducts in the liver are destroyed. The drug is being tested for the condition in a late-stage study. However, seeing the statistically significant improvement in patients and the promising results of the trial, the United States Food and Drug Administration stopped the trials midway, and approved it for the treatment of NASH. Intercept said the safety committee made the recommendation after reviewing liver biopsy data from about half of the 283 patients enrolled in the mid-stage trial. The company's shares nearly quadrupled to a life high of \$305 on the NASDAQ, valuing the company at about \$6 billion. "We didn't expect this data until the fourth quarter," Wedbush analyst Liana Moussatos said. "It's a huge opportunity for the company as there are over 10 million patients worldwide."



Obeticholic acid (OCA) composition.

However, shortly after; the National Institute of Health (NIH), who sponsored the trials revealed that patients who received the drug during the trials had aberrant cholesterol levels, compared to the patients that received the placebo. The NIH described the lipid abnormalities as "increased total cholesterol," with increased low-density lipoprotein cholesterol, also known as LDL or "bad cholesterol," and decreased high-density lipoprotein, or HDL, also known as "good cholesterol." Elevated LDL and reduced HDL levels are considered to be major risk factors for heart diseases.

The point of debate here is whether accelerating approval of drugs is justified. In certain scenarios, it is. It is extremely crucial to get the drug into the market for certain orphan diseases, where there is no other scope and the

patients are in dire need of treatment, as it was in this case. The FDA's proactive decision was a respite to millions of patients worldwide. Getting the product on the market was astute judgment and the right call by the FDA. On the other hand, safeguarding the best of the public's interests by ensuring appropriate safety and efficacy of products is also extremely vital. Insufficient data garnered by inadequate trials may lead to unforeseen repercussions, which may cause more harm than good. While exemptions may stand vindicated in certain cases, the trick lies in accurate risk-benefit assessment, which will have a wide-reaching impact on the approval of products in the health-care industry. ■

# The Grand Re-Opening of Psilocybin

BY JOSHUA TIMMONS, BIOLOGY, , 2016

**M**ost people are familiar with the bad: several types of hallucinogenic mushrooms are lethal. Recommended dosages of the Schedule One drug aren't known. And, worse yet, telling your grandmother you tried some will probably give her a heart attack. But those issues aside, emerging research into hallucinogenic mushrooms is revitalizing a field of psychopharmacology that's been dead for over 40 years.

It all dates back to the 1960s with one eccentric Harvard professor, Timothy Leary. In the drug-fueled '60s, he was a shaman in the emerging field, but his approach was more in line with a crazed fanatic than a research professor; he popularized the catchphrase "Turn on, tune in, drop out," and actually tried founding a religion based around his drugs.

But maybe a religion would be fitting for hallucinogenic mushrooms, considering the claims in the preliminary research. In a 2011 John Hopkins study, 18 healthy adults (average age 46) were given variable doses of psilocybin, the active ingredient in mushrooms. Fourteen months after five eight-hour sessions, 94 percent of the participants were rating their experience as one of the "top five most meaningful" of their lives, with 39 percent saying it was the single most meaningful. For some, the experience was in line with a spiritual awakening; to others, it was a deep emotional journey. In post-study surveys, many of these test subjects rated it among their most memorable personal experiences, akin to childbirth and parental death.

In a follow-up study with a different focus, 60 percent of participants went on to experienced a measurable personality change lasting longer than a year. Among the changed attributes were an increase in acceptance of new ideas,

experiences, and perspectives. "It was sort of like an anti-inflammatory for the ego," said one participant, a 50-year-old scientist. An interesting result of these personality changes was that they ran counter to the typical age-personality correlation. Older participants showed personality characteristics of people decades younger than their actual age, with a new propensity for openness.

The most obvious question to come out of all this is "how?" British neuroscientist Robin Carhart-Harris has used magnetoencephalography—a technique that measures neuroelectrical activity over time with more precision than an fMRI—as the basis for his hypothesis that psilocybin interrupts our brain's sense of self. This idea meshes with the ubiquitous claim of a "disappearance of ego" that participants have experienced. This sense of disintegration could underlie participants' descriptions of the experience as "spiritual." Another more easily explained component of the drug is the targeting of serotonin, a mechanism shared by the ubiquitous medication Prozac.

The potential for use in therapeutic settings is there, says John Hopkins researcher Roland Griffiths. "I think we're seeing a sea of change, and it's now become acceptable to conduct these trials under very careful conditions. It's very interesting from a scientific point of view."

Important to note is that these preliminary studies are conducted in a regulated manner: Study participants took the hallucinogen in a living room environment with pre-selected music and a guide familiar with the experience. In a survey of 1,600 recreational users, only 40 percent ranked drug usage experience among their top five most meaningful life moments, as opposed to the 94 percent from the John Hopkins study. It's likely that the controlled factors combined with psilocybin give rise to the resounding claims of the John Hopkins participants.

Despite emerging results, the general public still looks on mushrooms with ambivalence; even within the scientific community there is a reluctance to be associated with hallucinogens. Much of this is due to outdated concerns from a culture war only a portion of the population now remembers. For a little perspective: One in 10 American adults are now taking antidepressants. Additionally, too much caffeine can cause an anxiety attack, and a single bottle of alcohol has the potential to kill someone, yet neither has undergone the complete excommunication that hallucinogens did 40 years ago. Perhaps psilocybin is a research opportunity pushed from the table because of fear rather than pragmatism.

"As a culture, we experienced such trauma because of what happened in the 1960s – not just here, but worldwide," Griffiths explains. "It's really quite unprecedented to have a situation in which a unique and very interesting compound is simply not studied for a long period of time."

Whether psilocybin is found to have a significant effect on depression, anxiety, and addiction as proponents claim remains to be seen. The branch of research within psychopharmacology is just beginning its revival and no one wants to repeat the overenthusiastic mistakes of professor-turned-fanatic Tim Leary. The only thing for certain is that time will tell. "There may be applications for this we can't even imagine at this point," Griffiths says. "It certainly deserves to be systematically studied." ■





# Curing Blindness with Gene Therapy

BY GWEN SCHANKER, JOURNALISM, 2018

For more than 20 years, scientists have explored gene therapy as a way to cure genetic diseases, including hemophilia, muscular dystrophy, and sickle cell anemia. Despite initially high expectations, the technique has historically enjoyed limited success, failing to live up to its original hype. Today, new research offers hope that the process of gene therapy is finally emerging as a realistic solution to genetic conditions, specifically blindness.

The *Lancet* medical journal recently published results of a trial, led by Oxford professor Robert MacLaren, which used gene therapy to treat patients with a rare form of inherited blindness known as choroideremia. Choroideremia causes the sight of affected individuals to deteriorate as they age, eventually leading to blindness in middle age. The x-linked recessive disease occurs in about one of every 50,000 people in the U.K., and it usually affects males. Physiologically, the condition

is caused by a mutation in the gene CHM, which leads to the deterioration of a tissue layer between the white of the eye and the retina.

In general, gene therapy occurs through insertion of a therapeutic protein into an adenovirus vector within a strand of DNA. The entire package is introduced into the cell, and the DNA is expressed by the cell's system. The expression of the new gene often changes the DNA and RNA transcripts used to synthesize proteins, and the cell begins to produce the new therapeutic protein, thereby treating the genetic disease. In the treatment of choroideremia, researchers introduced a functioning version of the CHM gene into a vector containing a virus similar to the common cold. Scientists then detached the retina of the patients' eyes—a potentially dangerous process—and inserted the functioning gene underneath.

Scientists carried out the operation, which is similar to cataract surgery, in one eye in a total of six patients with varying degrees of vision impairment. Two of the patients had near-perfect vision, two had fairly good vision, and two had reduced vision, or acuity—a term that refers to the acuteness or clarity of vision and is measured by patients' ability to read lines of letters on a sight chart. No patient reported worsened eyesight as a result of their operation.

Within six months after the surgery, those who originally had excellent or good vision reported the same level of acuity, but had slightly more enhanced vision in the dark. Patients with reduced vision saw significant improvements; for example, Jonathan Wyatt, 63, who was barely able to see pre-operation, became able to read three lines further down on an optician's sight chart. Further adding momentum to the gene therapy movement, Wyatt's improvement has been consistent for nearly two years, giving MacLaren and others hope that they have found

a permanent solution for vision impairment.

MacLaren and his associates were funded by the Health Innovation Challenge Fund, and also received additional financial support from other outlets, including the NIH, the Oxford Biomedical Research Center, and the charity Fight for Sight. The trials so far have demonstrated that the adenovirus vector can deliver crucial DNA without damaging the retina, which was an early concern of the researchers. Based on the success of the first six patients, MacLaren and colleagues have tested three more with a larger amount of the corrective gene. It is too soon for MacLaren to draw conclusions from this second round of trials, but the new patients appear to be responding positively.

Though the number of trials that MacLaren and his team of researchers carried out is small, the potential implications of the study are tremendous. The scientists believe that if the results continue on a positive track, gene therapy could be used to treat other, more common forms of blindness. This includes the condition known as age-related macular degeneration, as well as glaucoma, both of which affect a much greater number of people than does choroideremia.

After initial hype and the ensuing few disappointing decades, the field of gene therapy appears to be making a comeback. MacLaren has demonstrated that the process can successfully be used to treat a specific form of blindness, without causing further damage to the eye. Further trials and experiments, carried out by both MacLaren's group and other research teams, will stand to clarify just how influential gene therapy can be in the global healthcare arena. ■



# Targetting Tumors with Gene Therapy

BY JORDYN HANOVER, BEHAVIORAL NEUROSCIENCE, 2017

Scientists have found a new, yet undeveloped gene therapy method that is able to target specific cells or masses without compromising the rest of the body. At Washington University in Saint Louis, researchers have developed a method of injecting a deactivated virus into the bloodstream to directly affect a targeted area.

In a study published in *PLOS ONE*, researchers showed that this gene therapy method could target specific tumor blood vessels in mice without affecting healthy cells and tissues. Professor David T. Curiel, who co-authored the study with Professor Jeffrey M. Arbeit, commented that this development would allow an expansion of the gene therapy field beyond the options in use today. At this time, doctors typically consider only blood and bone marrow for gene therapy, as they are substances that are easily removed, treated, and replaced in the body. There are currently no effective, highly-targeted gene therapies for areas such as the brain, lungs, and heart.

Arbeit and Curiel's team demonstrated that certain vectors (deactivated viruses) directly attacked malignant tissues, but not healthy organs. In the initial studies, the injected vector also contained a fluorescent green component that would illuminate the metastatic tumors and the blood vessels that sustained them. The vector itself contained a portion of gene associated with tumor lining and growth. In addition, the scientists used an anti-clotting drug in conjunction with the viral vector to prevent the vector from accumulating in the liver upon infusion. Thirty-six mice that were two to three months old were used as subjects in the trials.

Published in late December 2013, the project found that the viral vector used in the study successfully targeted the transcription phase of cells that line malignant tumors present

in mice. The study also showed the enhanced capabilities of the vector; in a case where cancer had metastasized to other parts of the body, the vector identified those tumors in addition to the initial targets. However, the study also noted that further vector optimization would be necessary before moving on to further testing stages.

**“We want to hijack them and turn them into factories for producing molecules that alter the tumor microenvironment so that it no longer nurtures the tumor.”**

“We don't want to kill tumor vessels,” Arbeit explained to *Medical News Today*. “We want to hijack them and turn them into factories for producing molecules that alter the tumor microenvironment so that it no longer nurtures the tumor.” In practice, this concept could be applied to current cancer treatments, potentially aiding the restriction of tumor growth. The new method would allow for a direct effect on the targeted tissues, leaving the healthy organs untouched.

The implications of this study are staggering. With the expansion of vectors that target specific cells, scientists may eventually be able to use this method in diseases other than cancer—for example, diseases that come directly from the genetic code. If these studies' successes continue, it is possible that diseases like Alzheimer's or Parkinson's, which have distinct genetic markers, could be targeted by gene

therapy and be either blocked or genetically altered to slow or stop their progression completely. Arbeit said that after 30 years of research, scientists still are not able to inject a deactivated virus into a human to target specific cells and have the virus act as intended. As the research continues and the use of these viral vectors is implemented and studied further, perhaps in the next 30 years, the scientific community will be able to achieve that goal. ■



# BONES FROM THE DEEP

BY KATIE HUDSON, MARINE BIOLOGY, 2017

**E**volutionary biologists are always looking to determine how different organisms have evolved over time. To do this, they often focus on how and when specific characteristics evolve in order to construct phylogenetic trees from the data that show the order of evolution within a group of organisms. These characteristics can range from one as simple as wing coloration to the development of hair or feathers. Through these efforts, scientists have taken the first step in determining how some internal structures and characteristics have evolved. In a study that was published in *Nature* in early January, scientists believe they have come closer to discovering how bones evolved.

To make this find, a research team from universities and institutions across the world (based primarily in Singapore) sequenced the genome of one of the ocean's "living fossils" - the elephant shark, *Callorhinus milii*. The elephant shark is member of the group of cartilaginous fish known as chimaeras, which are related to sharks and rays, that inhabits the deep ocean around Australia and New Zealand. Cartilaginous fishes lack rigid bones; instead, they have a flexible, cartilage-based skeleton.

Researchers chose to sequence the genome of the elephant shark because of its relatively small genome. The genome of the elephant shark is made up of approximately 1 billion base pairs, which is around the third the size of the human genome. This made sequencing the genome fairly easy. It was also chosen because few genomes from sharks, rays, or chimaeras have been completely sequenced.

Another factor that influenced the selection of the elephant shark was its evolutionary history. It is estimated that the elephant shark evolved approximately 420 million years ago. In that time, the elephant shark has evolved slowly, if at all. This means that its genome was very similar to the genomes of the organisms present at the time in its evolution, which could allow the researchers to draw general conclusions about bone evolution in bony fish in the future.

The research team took advantage of this difference when trying to determine how bones evolved in vertebrates. The genes needed for bone formation had already been determined, so the focus of the research was to determine what was missing from the elephant shark genome.

After the genome was sequenced, it was determined that the elephant shark genome contained most of the genes required for bone formation. The genes that were absent were a group of genes responsible for producing a protein complex that converts cartilage into bone, known as the secretory calcium-binding phosphoprotein genes. To determine that

this gene family influenced bone formation, researchers silenced the same gene group within a population of zebrafish. They found that the zebrafish with the silenced genes were not able to grow bone as effectively as those that had the genes, suggesting that the gene group has a significant influence on bone development.

The research team also discovered that the elephant shark's genome may also hold the keys to understanding the evolution of the immune systems of vertebrates. They found that the elephant sharks have killer T cells which destroy

Evolutionary biologists hope that the data about bone evolution will help add more details on how life progressed onto land through the evolution of fins. John Postlethwait, who studies Antarctic ice fish at the University of Oregon in Eugene, hopes to use the data in his research to determine how the ice fish lost the ability to grow bones through evolution. The research team believes that the elephant shark's genome is the best window into the genomes of extinct fishes and hopes that it will be used to determine how many of the complex systems present in extant



cells that have been infected by pathogens, but lack helper T cells that help identify pathogens and regulate overall immune response. Previously, scientists believed that killer and helper T cells evolved at the same time but these new findings suggest that they evolved in a two-step process. It was also discovered that the elephant shark lacks the immune cells that prevent autoimmune diseases.

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**“Doctors hope that the research can be used to understand bone diseases like osteoporosis.”**

The construction and analysis of the elephant shark's genome has intrigued scientists and opened up many doors for future research projects, especially in the medical field. Scientists and doctors hope that the research can be used to understand bone diseases like osteoporosis and to develop more effective cures and treatments to those ailments. They also want to utilize the data collected on the immune system of the sharks to eventually be able to fine tune the human immune system.

animals, including humans, evolved. They hope that it will be the basis of comparison in many genome studies to come.

After the promising results of this study, many research teams are currently beginning projects to sequence the genomes of the many relatives of the elephant shark, including sharks and rays, to see if they are missing the same or similar gene groups. By sequencing the genomes of similar organisms, they hope to construct the entire story behind the evolution of bones and the skeletal system. Eventually, they may be able to determine how many of life's complex internal systems evolved and, gene by gene, bring scientists one step closer to determining how life began. ■

# Shark Culling: Catch-and-Kill with the Future in Mind (or Not)

BY AYESHA GALADARI, PSYCHOLOGY, 2018

**A**ustralia is home to various species ranging from cockatoo birds to sharks. While there are many species that are harmless, there are a considerable number of dangerous and potentially life-threatening creatures. As a result, awareness is considered the best weapon to help protect any person from being harmed by a dangerous organism, whatever it may be. There are rules and regulations that set the tone and guide individuals to the steps that should be taken; policies exist to protect the citizens and even tourists from potentially dangerous species. An example of these policies would be shark culling. The question that arises is: how far are people willing to go in order to protect themselves from danger?

The problem with waving a red flag at the sight of any top predator is that oftentimes, the presence of that specific animal actually indicates the stability of the delicate balance of the environment. For example, out of the known 370 species of sharks around the world, 160 inhabit Australian waters, with more than 100 located in the Western Australia. They play an important role in the areas of the ocean where commercial fishing occurs and

serves as an indicator that the marine environment is balanced. The main issue is the potential disaster that can take place when a shark comes in close contact with a human. Therefore, many agree that there should be a protocol that takes place in the event of a shark sighting, to protect both humans and the marine ecosystems.

The danger of shark attacks has led to the creation of an emergency hotline to call in case of a shark sighting in the beaches, and the implementation of a Shark Hazard Plan, which involves a chain of action that includes government agencies, local councils, and community groups. It aims to reduce the risk of shark interactions. Additionally, after the occurrence of several shark attacks within the past year that claimed human lives, the Western Australian government implemented a shark culling policy to capture and kill any shark measuring over 3 meters in length, regardless of species.

The new plan has been put in motion and will remain in place until the conclusion of this year. Culling is a method of luring in sharks by sending out bait and killing them after capture. It is a process of "controlling the population."

Baited hooks have already been placed up to 1 kilometer out to sea from beaches, and squads are already in place to shoot and kill any sharks measuring over the length limit, including great white, tiger, and bull shark species.

This decision was met by mixed reactions, but mainly shock from a considerable number of individuals; 80 percent of Australians and environmentalists oppose this plan. They are opposed to the brutality of the process, the danger to vulnerable species, and the damage it can potentially inflict on the ecosystem. It is inevitable that other species that have caused no harm whatsoever will also be captured. They argue that educating the public and raising awareness by using technological advances combined with other strategies such as netting, can be just as efficient and effective. In addition, the demise of certain species will have a great effect on the overall population of the sharks and will potentially harm the migration system. If we disrupt the natural distribution of the different types of sharks, and put the vulnerable species at risk, who is to say what will happen in the future in terms of the ecosystem's health? ■

## Fact Check: *Blackfish*

BY ANDREW BLOY, BIOLOGY 2017

**A**t the 2013 Sundance Film Festival, a documentary was introduced that has since made quite a splash. That documentary is called *Blackfish* and it highlights the concerns and dangers in keeping orca whales in captivity. One of the biggest issues represented in *Blackfish* is the assertion that orcas that live in SeaWorld parks do not live as long as their wild counterparts. *Blackfish* claims that orcas rival humans in terms of longevity; SeaWorld claims that they only live to be about 35. The question is, who is telling the truth?

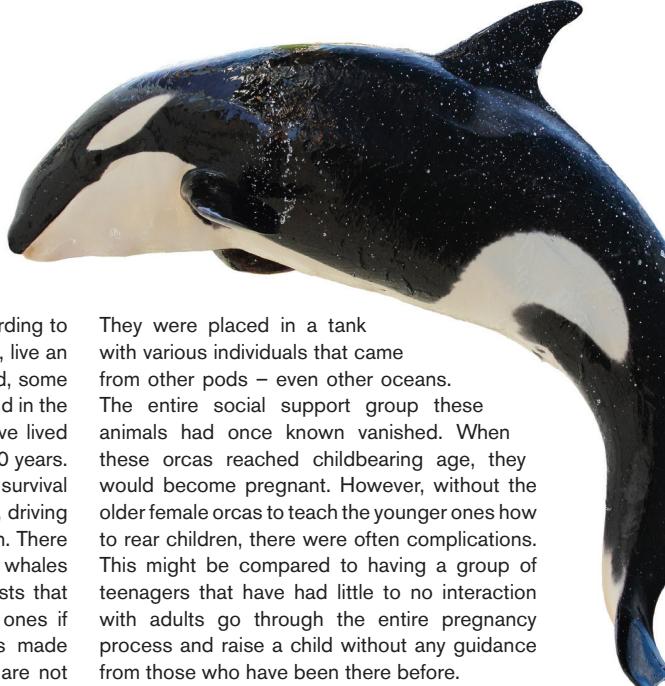
One of the main arguments made in *Blackfish* is that wild orcas have life spans that are comparable to that of humans, with one interviewee claiming that they can live up to 100 years old, while those that live in SeaWorld generally die young. While it is true that wild blackfish can live up to 80-90 years old in some circumstances, National Oceanic and Atmospheric Administration data puts the life expectancy for wild orcas at about 30 years for males and 50 years for females. This is not

nearly comparable to humans who, according to a 2011 World Health Organization study, live an average of 70 years. With that being said, some SeaWorld orcas live as long as ones found in the wild. SeaWorld has four whales that have lived past the age of 30, with one living over 40 years. However, the caveat is that there is a low survival rate for newborn killer whales in captivity, driving the life expectancy of captive orcas down. There is truth to the statement that captive whales do not live as long, but the data suggests that captive orcas can live as long as wild ones if they survive infancy, so the statements made in *Blackfish* about their life expectancy are not necessarily accurate.

The low survival rate of orca calves can be attributed to many factors, primarily stress and lack of knowledge on how to rear young: consequences of their captivity. This causes numerous complications such as early pregnancy age, stillbirths, and defects in calves. When the first orcas were captured to be kept in captivity, they were young, easily transported individuals.

They were placed in a tank with various individuals that came from other pods – even other oceans. The entire social support group these animals had once known vanished. When these orcas reached childbearing age, they would become pregnant. However, without the older female orcas to teach the younger ones how to rear children, there were often complications. This might be compared to having a group of teenagers that have had little to no interaction with adults go through the entire pregnancy process and raise a child without any guidance from those who have been there before.

Another factor to consider is that many of the orcas that survived infancy in SeaWorld parks have not had the time to be judged accurately on their longevity in captivity. Is *Blackfish* telling the truth about orca longevity? Not entirely, but then again SeaWorld is not entirely blameless either. Only more time and data on this subject will allow researchers to offer any definitive answers. ■



# Computers Curing Cancer

BY GRACE SEVERANCE, BIOLOGY & PHILOSOPHY, 2018

In 2011, the supercomputer IBM Watson made history by outperforming two human contestants to achieve first place on the television game show "Jeopardy." Now, Watson's abilities are being utilized for a greater purpose: it is assisting physicians and researchers at MD Anderson Cancer Center in the fight to eliminate cancer. Doctors will have access to Watson on computers and portable electronic devices, allowing them to harness Watson's advanced cognitive capabilities in order to draw conclusions from patient files, current research, and past medical histories, and then suggest the best treatment options for a specific patient.

Watson's great potential in the medical field stems from the same principle that allowed it to triumph on "Jeopardy." The supercomputer was designed to analyze information in a manner similar to the human thought process, but on a much larger scale. Watson can mine huge data troves to answer critical questions about a patient's cancer treatment plan. Physicians can then relay Watson's analysis to their patients as

they decide what step to take next in the patient's care. Watson has already been integrated into a device called the Oncology Expert Advisor (OEA) and will play an important role in APOLLO, a technology-oriented part of MD Anderson's Moon Shots program, a new collaborative at the Cancer Center, to attack some of today's most prevalent cancers, including leukemia, melanoma, and lung, prostate, and breast cancer.

This new method of attacking cancer has the potential to revolutionize the medical field. One of the biggest challenges currently facing the medical community is the extraction of clinically relevant information from vast amounts of data. Watson provides the opportunity to channel data from doctor's notes, clinical trials, patient histories, and research labs into one system. Clinicians hope that Watson's incredible computing and cognitive abilities, in addition to its human-like processing, will uncover small details and connections in this vast pool of knowledge that would have been overlooked by even the best physicians. As IBM's General

Manager Manoj Saxena explains, "IBM Watson represents a new era of computing, in which data no longer needs to be a challenge, but rather, a catalyst to more efficiently deploy new advances into patient care."

The application of Watson's abilities comes at a critical time in health care: the American Cancer Society expects 1.6 million new cancer cases in the United States this year. Watson's data analysis can help to manage this influx by creating a tailored treatment plan for each patient. It might suggest chemotherapy, a new combination of drugs, or even new clinical trials that the patient is best suited for. Watson is also expected to provide new information to researchers, driving innovation in the search for novel cancer treatments.

The integration of cutting edge computing technologies such as Watson into the medical community represents a new realm of possibilities for patients and researchers alike. Perhaps in the end it may be an artificial device that finds a cure to the most devastating human ailments. ■

## Stress Eating

BY JESSICA MCINTIRE, BEHAVIORAL NEUROSCIENCE, 2014

It's no secret that stress can influence dietary choices. Every student has had moments, usually in the middle of midterms or finals week, when he or she walks into a convenience store and a pint of Ben and Jerry's suddenly reaches out as a beacon of happiness and prosperity. Studies prove that this experience is perfectly normal. Assessments of European adolescents showed that high levels of perceived stress are an accurate predictor of poor diet quality. In fact, participants don't even have to taste the food to experience the relaxing effects: a study in which fatty acids were injected directly into the stomach rather than eaten yielded the same positive effect on mood. So, why is it that junk food becomes so much more appetizing when students experience anxiety?

It's probably because the high calorie content of a bowl (or three) of ice cream would have given early humans the energy to withstand stressful situations, thus providing them with a survival advantage during challenging times. In the 21st century, the most effort necessary to procure a meal involves choosing between Wings Over Boston and Five Guys, but in prehistoric times, high-calorie foods were a scarce resource. Motivation to work hard to locate food sources arises from a neurological pathway, developed through evolution,

which rewards people when they eat.

Food intake is communicated to the brain directly through the vagus nerve in the gut, and also through monitoring levels of nutrients in the blood stream. Especially following ingestion of foods high in fat and sugar, the brain responds by triggering the increased release of relaxing hormones, such as dopamine, serotonin, and opioids, while reducing levels of stress hormones like cortisol. Drugs that elevate dopamine and serotonin are used as antidepressants, and opioid hormones mediate heroin addiction. Effectively, humans are addicted to food, and foods high in calories are the drug of choice because they elicit the strongest neurological response.

Prehistorically, periods of stress were associated with intense physical activity, and subsequent elevated calorie intake was vital for replenishing energy stores in the body. Nowadays, periods of stress are associated with events like financial loss, social situations, or exams, which are more or less sedentary activities relative to a fight or flight response. Modern stress-inducing stimuli, despite differences in energy demands, are nearly identical to predator threats in terms of their



physiological impact. Therefore, they still cause humans to seek out high-calorie foods even though almost no physical energy is expended.

It's unfortunate that foods most often eaten in response to stress are also linked to diminished health. Luckily, there are foods that reduce stress but are also miraculously healthy. Complex carbs like whole grains can elevate mood along the same serotonergic pathway as candy, but because they are digested more slowly, they produce more stable fluctuations in blood sugar and emotion. Oranges and other foods rich in vitamin C can reduce levels of stress hormones while supporting the immune system, lowering stress as well as the risk of catching a cold during finals. Fish contains Omega-3 fatty acids, which prevent drastic spikes in stress hormones so students can keep their cool. While coffee has been shown to worsen agitation, people who drink black tea regularly tend to have lower levels of cortisol in response to stress.

High-calorie dietary trends are hardwired into the body's neurological chemistry. By being aware of these unhealthy tendencies, humans can recognize cravings and choose a nutritious, but still stress-relieving, alternative. ■



# Primate Energy Expenditure

BY DAVID ADAMS, CHEMICAL ENGINEERING, 2017

A recent paper authored by Hunter College anthropologist Herman Pontzer, and internationally coauthored by over a dozen scientists, suggests that primates, including humans, burn only half the amount of calories per day compared to similarly sized mammals. The surprising results may help to explain why the life span of human and other primates are longer on average compared to other placental mammals.

In order to study how much energy an animal burned, a non-invasive procedure called doubly-labeled water was used on zoo animals. Special isotopes of hydrogen and oxygen were placed in the drinking water supply of the species being studied; after the water was consumed the atoms were used for energy expenditure within the cells of the body. Looking at waste products, scientists could detect the rate at which metabolic processes used up the labeled isotopes. Performing this entire procedure took anywhere from 24 hours to 21 days depending on the subjects metabolic rate. One downside of the procedure is that it requires usage of expensive and complex equipment such as a mass spectrometer, however, it gives a very accurate reading for total energy usage over time.

The scientists involved in the study wanted to ensure that uncontrollable variables involved with studying zoo animals did not hurt their results. In order to account for this, wild mammals had to be brought into the study for comparison. In some cases the diet of a mammal in its natural habitat was carefully tracked over long periods

of time. Mostly though, an array of academic papers on energy expenditure were referenced to collaboratively gather results.

Interestingly, it was found that the total difference in energy expenditure between captive

**“On average a human burns 2,500 kilocalories per day, while placental mammals of similar mass use in the range of 5,000 kilocalories or higher.”**

mammals and those found in nature was negligible. A number of possibilities could account for this. For one, the activity level of zoo and laboratory animals could be higher than what was previously thought – enough to match the struggles of survival in nature. Another idea posited by Pontzer and the team is that the metabolic rate of a mammal is much more reliant upon genetics than on the energy consumed during physical activity. On average a human burns 2500 kilocalories per day, while placental mammals of similar mass use in the range of 5000 kilocalories or higher. The paper points out that to make up such a large gap in energy usage, an average human would have to walk the equivalent of a marathon each day.

Even before advances in medicine and nutrition humans have experienced great life expectancy. If a pre-modern human lived beyond the tumultuous and often deadly first two years of their life then they could reasonably expect to see 70 years of age. This life expectancy is decades longer than most placental mammals of similar size and appears to be closely linked to the small total energy expenditures in humans.

Mammals with shorter life spans often reach sexual maturity at a very young age and have short gestation periods. However, their rapid growth is often balanced by their inability to respond to changes in an environment, particularly when these changes bring scarcity in food or other resources. It appears that having small daily energy expenditures is the “slow and steady” strategy that allows for adaptability in most primates. It also seems to allow for greater brain development and other unique characteristics seen in this family of mammals. Whether the results presented in this paper have provided the key to understanding human life expectancy or just another piece of the puzzle is yet unknown; Pontzer and the other researchers involved in the study will continue their important work to find out. ■

# New Device Claims to Let Humans Breathe Like Fish, James Bond, or Jedi.

BY CLAUDIA GEIB, JOURNALISM & ENVIRONMENTAL SCIENCE, 2015

In the 15th century, Leonardo da Vinci described some of the first recorded underwater breathing apparatuses in his book Codex Atlanticus. However, da Vinci declined to divulge the details of these devices; fearing that readers would take advantage of this technology to sink ships and even commit murders. Over 500 years later, movie spy James Bond astounded audiences with a tiny device called a rebreather, which instantly converted water into breathable oxygen and could fit undetectably into his tuxedo pocket. Bond used his rebreather to accomplish just what da Vinci had feared: murder, mayhem, and lots of ship sinking (all in service of Her Majesty the Queen, of course). Fortunately, Bond's rebreather does not exist.

Or does it?

A South Korean inventor named Jeabyun Yeon claims to have developed a device capable of drawing oxygen from water. His invention, the Triton Oxygen Respirator, supposedly operates as a synthetic gill, extracting oxygen from the water through "fine threads with holes smaller than water molecules." Fans of the Star Wars

series will recognize the Triton as remarkably similar-looking to a rebreather used in *The Phantom Menace*.

Although many researchers have pursued the artificial gill concept, none have been able to develop a working model. Still, underwater exploration has progressed significantly since da Vinci's time. In the 15th century, the breathing apparatuses that troubled the great inventor were not much more than jars turned over a diver's head or air-filled leather bags attached to a hose. Today, divers can spend hours beneath the sea and reach depths of over a thousand feet. In fact, a real device called a rebreather even exists, and is used to remove carbon dioxide from exhalations so divers can reuse air they have already breathed.

If functional, a Bond-worthy device like the Triton would make such technology obsolete. Current underwater breathing apparatuses require divers to carry tanks of pressurized gas during their watery adventures, which makes "gearing up" and travelling on land with dive equipment an arduous process. In contrast, the

Triton is not much larger than a common diving mask; users need only bite down on the snorkel-like mouthpiece to receive oxygen.

Before lining up to purchase a Triton, however, excited underwater explorers should know that the technology by which it is theoretically powered is not known to exist. The device utilizes a micro compressor and a micro battery that is 30 times smaller than existing batteries and capable of charging 1000 times faster. If the doubtful existence of these components does not cast doubt on the Triton's functionality, good old physics might do the trick. The relatively large amount of oxygen required by humans means that the Triton would have to pump a massive quantity of water (estimates range between 20 and 50 gallons) through its system to provide one minute of oxygen to a diver.

It seems that until our technology catches up with our imaginations, the Triton may remain the stuff of movies—and Leonardo da Vinci can continue to rest easy. ■

# New Ligament in Knee is the Missing Link

KAYLA GOMES, PHYSICAL THERAPY, 2017

The ankle bone is connected to the shin bone...the shin bone is connected to the leg bone... and the knee is that connector. Like all joints classified under the synovial/diathrosis category, the bones in the human knee articulate via cushioning cartilage, which is encased in a pocket filled with lubricating fluid, and are held together by ligaments. Ligaments, made up of dense, regular connective tissue, are quite strong so that they can keep joints stable throughout a variety of movements and vigorous stresses.

There are four main ligaments in the human knee. The two cruciate ligaments, the anterior cruciate ligament (ACL) and posterior cruciate ligament (PCL), cross each other through the joint and predominantly control the movement of the tibia – the shin bone. On either side of the knee, two collateral ligaments provide stability to the inner and outer knee. These ligaments are fairly susceptible to injury, especially in individuals who participate in intense, pivot-heavy sports such as soccer or basketball. Annually, there are more than 200,000 ACL injuries alone, half of which result in knee reconstruction surgeries.

A few years ago, Dr. Steven Claes, an orthopedic surgeon, and his colleagues in Belgium noticed something strange in patients who had undergone such ACL reconstruction

surgeries. Despite reconstruction, patients' knee joints would give out when they moved, even though their joints appeared healthy; something wasn't right. What could be causing these patients' extreme joint weakness when the apparent problem had been solved? Perhaps the answer didn't completely lie with the ACL, but in a completely different element of the knee altogether. Dr. Claes said "I know it probably sounds crazy to say that we thought there might be this new ligament."

It did sound crazy. After hundreds of years of human dissection and countless leaps and bounds in the advancement of medical imaging, how could doctors throughout history miss something as anatomically large as a ligament? As it turns out, one doctor didn't. In 1879, French surgeon Paul Segond hypothesized that the four known ligaments in the knee alone would not stabilize the knee enough. Without additional ligaments for support, the knee would be unable to handle the rigors of everyday life. Segond did find what he described as a "pearly, resistant fibrous band" connecting the lateral end of the femur and tibia, which would give support to the outer knee. Segond named this new finding, but it was eventually forgotten or ignored as a continuation of other tissues for over a hundred years, until Dr.

Claes and his team began the search again.

Knowing where to look because of patients' injury locations and past examinations from figures like Segond, Claes and his team searched 41 donated cadaver knees for the elusive cause of their patients' knee joint buckling. In all of the knees but one, they found a ligament separate from the iliotibial band that connected the femur and the tibia. Due to its location on the outside, front position of the knee joint, Claes and his team dubbed the re-discovered ligament the aterolateral ligament, or the ALL. In the one knee without an ALL, Claes speculated that the ALL may have been severed due to injury and withered away.

This discovery weighs heavily for Claes's current patients and all future ACL patients. When re-examining the knee scans of some of his patients with ACL injuries, Claes found injuries to the ALL as well. Claes and his team are currently planning and practicing how to perform surgeries on the ALL, but research is still speculative and cautious due to the lack of understanding of this "newly discovered" ligament. However, as Claes iterates, recognizing the ALL is "an important step forward" in how doctors will examine and treat knee injuries, especially ACL injuries, in the future. ■

# Go GREEN

## Get Home

BY NATASHA MATHUR, BEHAVIORAL NEUROSCIENCE, 2017

**M**ost people have a love-hate relationship with electricity: love to use it for all of their daily needs, but hate the huge bill at the end of the month. And of course, there is the constant promotion of the idea of "going green." But a new development in the field of electricity may affect people's lives, environment, and wallets in the future.

Pierre Callejo, a French biochemist, has discovered a new way to effectively rid the air of carbon dioxide emissions while providing power to new streetlamps. How? Callejo placed microalgae in a large tube along with batteries. The batteries then charge through photosynthesis of the algae. The process of photosynthesis involves absorbing carbon dioxide from the atmosphere and converting gas into sugar that cells use as energy. In the case of microalgae, the algae stores the energy and then produces a bright luminescence.

This new lamp can be used in places like parking garages, where lights are very important, and cars pour out carbon dioxide all day long. Air quality in the garages would improve from these lamps, as microalgae release oxygen into the area while producing light. The lamps can also be used in neighborhoods, thereby creating little chance of a pitch-black street during a power outage. With no electricity required, the lamps could allow the reallocation of tax dollars to other projects.

One of the most important benefits of these new kinds of lamps is that they will be able to drastically reduce the amount of carbon dioxide in the air. Carbon dioxide is a gas that has a large impact on the environment by adding to the greenhouse effect, which traps heat in the atmosphere. Most electricity in the U.S. comes from burning coal, which releases carbon dioxide. Streetlights use a large amount of electricity in total, because they are in most countries and in most neighborhoods. Because of this, streetlights indirectly lead to the release of greenhouse gas. Decreasing electricity use would thus reduce the amount of carbon dioxide given off.

Another significant source of carbon dioxide emissions is transportation vehicles, which emit 4.57 million tons of carbon dioxide per day in the U.S. alone. By scrubbing this carbon dioxide out of the air safely and efficiently, Callejo's new initiative may very well decrease the amount of carbon dioxide in our air, reducing humanity's impact on the environment and giving people the satisfaction of "being green."

The microalgae can take in about 30 to 40 percent of the carbon dioxide humans use, according to Callejo, who recently spoke at a TED conference. The light a lamp emits is very soft, making it suitable for many environments. Callejo hopes to place these lamps not only outside, but also indoors, such as in industrial factories, which could benefit from the increase in clean oxygen as well as a decrease of carbon dioxide fumes. Callejo sees this as a solution to an issue that is becoming more and more evident as humanity builds more factories and uses more electricity.

Streetlamps are not the only innovation that use these handy little algae. Microalgae is now being mass-produced for use in phones as bioplastics, in cosmetics, and even in drugs. Because microalgae must protect itself from the same, or even harsher, environmental conditions that humans do, they produce unique compounds that cosmetic companies have begun to use algae in their products. Microalgae produces a mix of protective polysaccharides, given the trade name of alguronic acid, that acts as a skin-evening and anti-aging compound. Alguronic acid was determined to be more beneficial than other synthetically produced skincare items. Another use for algae comes from its production of bioactive compounds. These compounds can be used as antibodies, and more research is being done in order to use them for treating specific illnesses and disorders.

Though microalgae has made a splash in other fields, it may take some time for its presence in our streetlights to occur. The question is whether these lights will be funded and whether they will be affordable for towns and neighborhoods. If they do gain widespread acceptance, the environmental and financial benefits could be outstanding. The microalgae lamps provide a nature-based solution to a mostly man made problem. The fact that microalgae is not difficult to produce in large quantities, combined with Callejo's firm belief in the idea that the algae can really help with the greenhouse effect, inspires others to believe this idea may truly work. Someday it may be commonplace to see shining green lights while walking home or while searching for your car in the parking garage. ■



# NUSci Axolotl Questions:

## An Interview with Stem Cell Researcher Dr. James Monaghan

BY JEN OBRIGEWITCH, BIOLOGY, 2017



Dr. James Monaghan is a recent addition to Northeastern University, but his lab is already growing heads over tails. Actually, his lab is growing tails over tails. He works with axolotls, a type of salamander with the extraordinary ability to regenerate lost limbs, even portions of the head, heart, and spinal cord. NUScience had the opportunity to speak with him about his research.

### Can you summarize your research for us?

I'm researching why some animals, such as the axolotl salamander, can regenerate so well, and humans do it so poorly. Once the reason has been discovered, the goal is to translate this knowledge over to human regenerative medicine. Then specialists in that field will work on regenerating structurally complex tissues for people who have suffered damage to their original tissue. The goal is to be able to easily regrow organs in a lab. The dream is to be able to induce regeneration in the human body.

### Why the axolotl?

There is no great explanation why axolotls regenerate so well, though many people turn to stem cell differences. Stem cells are unspecialized cells that are able to replace themselves indefinitely. Stem cells have the ability to turn themselves into specialized cells the body needs most, like muscle or nerve cells. Humans do have adult stem cells, but the stem cells in humans most often do not mount a regenerative response after injury. However, axolotls have the ability to re-tap into their developmental mechanisms, re-stimulate their stem cells, and regrow the parts of their bodies that need to be repaired. We humans are locked into our adult bodies. But the cells in axolotls are not. They don't just patch up old limbs, they completely regrow them. If a leg is somehow

removed from their body, stem cells surface and quickly begin to grow another one. It begins as a smaller version of the same leg, growing rapidly until it has matched the size of the previous leg and is completely indistinguishable from the one that it replaced.

### Is there anything that axolotls can't do as well as other animals because they spend so much energy regenerating?

It seems like other bodily processes don't suffer to make regeneration be possible. Axolotls can live for over 20 years, and they hardly ever get cancer. Drugs that cause cancer in mice are rarely able to cause cancer in axolotls. These guys are simpler than humans, but they also share many of the same basic body patterns—an axolotl brain can easily be compared to a human embryonic brain—as well as many genes. Entirely unique genes are probably not what enable them to regenerate. Instead, it's as though adult axolotl cells seem to turn back time to work in the developmental stage again.

### How do you feel about the portrayal of regenerative medicine in mass media? Do you think axolotls could replace lizards in the next Spiderman movie?

I have Spiderman hanging up in my lab, so you could say I've embraced the superhero-like capabilities of the animals. It's taught me that you shouldn't be completely serious about your work. Mass media is definitely interesting. But we won't be working on any evil lizards.

### What do you enjoy most about doing research in general?

The joy of research is that there are so many complex problems in regeneration that still need answers. Thinking about these problems then designing the proper experiment to test

your hypothesis, especially when you can see something visual under a microscope, is great. When a whole lab is working together on something, it's so much fun to test everything together and watch it all happen.

### How did you decide on this research topic?

I have always been interested in developmental biology and genetics, but my experiences during my PhD training sealed the deal. My PhD advisor was beginning his work with axolotl spinal cord regeneration and let me jump on the project. Ever since, I've been a salamander guy to the point that I even have a salamander on my ring.

### What advice would you give to an undergraduate scientist looking towards the future?

There are so many big questions left unanswered. It's not about what question you're asking. Whatever question it is, go all out when you're answering it. Put as much effort in as you can. There is no lack of problems that need to be solved. If you want to research with a faculty member, be truly interested in the research. It's a large commitment for a faculty member to take you on, so you need to show genuine interest.

### Is there anything else you want to let the readers of NUScience know?

I'm a new professor, and I can tell that Northeastern is the perfect place to meet my goals. I have undergraduates and graduates in my lab, and there are so many unique opportunities for them to jump ahead of the pack. They can decide and start their careers so much earlier than most people their age due to Northeastern's experiential learning approach, and I think that's really important. ■

# Researching White-Blooded Ice Fish in Antarctica

## An Interview with Urjeet Khanwalkar

BY LAUREN HITCHINGS, BIOLOGY, 2014

**N**UScience had the pleasure of interviewing Urjeet Khanwalkar, a student whose research on campus took him to the end of the earth for a one of a kind “snow-op” experience.

**Where did you do your most recent co-op?**  
I did my co-op at Palmer Station in Antarctica with Professor Detrich of the biology department after working in his lab on campus for the past two years. We spent five and a half months in Antarctica studying a unique species of ice fish by growing fish embryos and tracking their development over time. I was a research assistant, but I worked on just about everything, including designing and building the incubators we needed to grow the embryos in. We learned a lot about this species by studying their development and also from taking samples from adult fish.

**What was unique about the particular species of ice fish that you were studying?**  
Well, the ice fish species we studied, *c. aceratus*, is actually white-blooded, meaning that unlike most other fish, they don't have red blood cells and don't produce hemoglobin to carry oxygen. The ice fish can survive without hemoglobin for two reasons: One is because they have four times the amount of blood compared to similar species like *n. coriiceps*, a red-blooded relative, and the other is because there so much oxygen is dissolved in the frigid Antarctic water that the oxygen can just diffuse into the bloodstream. We are still hoping to learn more about how this works.

### **What were your living conditions like in Antarctica?**

They were actually a lot better than I expected. The station was fairly nice. In total there were 23 people on the station; only four of us were scientists, and the rest were mostly staff that kept the station running. We had a doctor, a chef, an IT guy; everyone was really nice. We had a large lounge for recreation time, as well as a bar, a sauna, and even an outdoor hot tub. We had pretty much everything needed at the station, except we ran out of fruits, vegetables, and milk—“freshies”—after just three weeks.

### **What were some of your favorite experiences from your co-op?**

One thing that was really fun was fishing in Drake's passage, which is considered to have some of the roughest waters in the world. Another favorite of ours was jumping into the icy cold waters and going swimming in just our bathing suits. We did it practically every Sunday. Otherwise it was just the everyday experiences like seeing wildlife such as seals, penguins, and birds. And then there was the evening skies down there which were always beautifully painted: the perfect twilight.

### **What was your worst experience there?**

The worst thing was probably getting there and finding out that there weren't any working incubators to do the research we had planned. I wasn't prepared to have to design and build those, and I didn't know exactly what kinds of conditions we needed to best grow the embryos, so we lost a lot in the process. I ended up

designing the best incubator in the end though, so at least it was a learning experience.

### **Would you recommend this co-op to other students?**

Oh absolutely. I plan on going down there again for my next co-op, and hopefully I will be able to work on some experiments on the effects of temperature. We want to see how the embryos will do if they are grown in water that is maybe 4 or 5 degrees warmer and see how they do. This could be relevant to what kinds of effects global warming might have on this species in the future. Really, this was a life-changing experience for me and I am glad to continue being involved. ■

Photos courtesy of Urjeet Khanwalkar.



# Resurrecting Ancient Water Fleas

BY MATTHEW TYLER, MARINE BIOLOGY & ENVIRONMENTAL SCIENCE, 2017

**S**cientists from the University of Oklahoma have successfully hatched 700-year-old eggs of the water flea *Daphnia*, giving the researchers a glimpse into the evolution of the freshwater crustacean and how humans have affected that.

*Daphnia* is a small freshwater crustacean, growing up to 5 mm long—just large enough to be seen by the naked eye. They live in lakes and streams, filter-feeding on algae and laying eggs in sediment at the bottom of the water column. In the 1990s, Dr. Lawrence J. Weider found dormant eggs in the sediment of German lakes, from which he initially developed his resurrection methods. Those eggs, however, were merely several decades old. Recently, Dr. Weider and colleagues discovered a still-more exciting find—*Daphnia* eggs which, according to lead-210 dating, were a staggering 1,600 years old.

These *Daphnia* eggs were found at the bottom of South Center Lake in Lindstrom, Minnesota. Surprisingly, the sediment where they were found was only a few feet deep. The oldest eggs could not be hatched, as Weider's



Photo courtesy of Wiki Commons

technique only worked on eggs 700 years of age or younger, but scientists could still extract DNA from them and compare it to other samples.

The sediment itself was the key to uncovering the biggest evolutionary changes of

these *Daphnia*. The older sediment had lower concentrations of phosphorus, a nutrient vital to all living things. As a result, the revived *Daphnia* collected and used phosphorus much more slowly—and thus, grew much more slowly—than modern *Daphnia*. Around 120 years ago, however, when industrialized agriculture began in Minnesota, phosphorus became much more abundant due to runoff from fertilized crops. With more phosphorus available, a small minority of faster-growing *Daphnia* took advantage of their adaptations and outgrew and out-compete the older slow-growing variants of *Daphnia*. That faster-growing strain of *Daphnia* is the only one still in existence today. Population changes of this kind, related to a trait that is passed to offspring, are the core of evolution; therefore, by introducing phosphorus to the bodies of water in the American Midwest, 19th century frontiersmen facilitated the evolution of these small crustaceans. ■

## Sexual Healing: Contact with Females Inhibits Aggression in Male Flies

BY KRISTEN DRUMMEY, BEHAVIORAL NEUROSCIENCE, 2017



Photo courtesy of Michael Drummond

**D**aytime television, from “Law & Order: SVU” or “Days of Our Lives,” will show that sex can play a large role in provoking aggressive behaviors that can have very serious consequences. However, Quan Yuan and his colleagues have recently uncovered evidence that sex may actually do just the opposite, at least in fruit flies. Yuan and his team have uncovered new information about the aggression circuitry in the brains of male fruit flies that could have implications on the study of human aggression.

Yuan's team studied aggression through behavioral assays of *Drosophila melanogaster*, a species of fruit fly that is commonly used in a wide variety of scientific research. Male flies often engage in aggressive behaviors with each other when they're competing for something, whether that be food, territory, or female partners.

In the study, two groups of male fruit flies were placed in the presence of virgin female fruit flies. One group of males did not have any prior sexual experiences and was considered “naive,” while the other group, which did have a prior sexual experience, was considered “experienced.” The team found that the naive group showed increased aggressive behaviors when a female fly was present, but the experienced group did not. When the female was absent, there was no difference in aggressive behavior between the experienced and naive males, suggesting that the differences between the two groups of male fruit flies were related to previous sexual experiences.

Yuan and his team decided to look into what neural mechanisms could be causing the differences in fly behavior. They found that contact between male flies and female

flies caused specific neurons to pick up on pheromones, which inhibit the aggression circuit. They tested different neurochemical systems that could be inhibiting that circuit and concluded that the GABAergic system might be modulating the aggressive behavior in flies. GABA is a neurotransmitter that is mainly responsible for inhibiting responses in neurons. To test their hypothesis, Yuan and his team manipulated GABA levels in the neurons in the aggression pathway and found that knocking out the resistant to dieldrin (RDL) GABA receptor led to no inhibition of aggression in male fruit flies, suggesting that it's an important component to modulating aggression seen in experienced males.

The findings of this study are only a first step but they eventually could have important applications for aggression research in humans. Discovering that GABA has such a drastic effect on the aggressive behaviors of fruit flies could lead to a better understanding of the neural circuitry of aggression, which could impact how aggressive behaviors in humans are studied and understood. ■

# Micro-windmills: The Future of Phone Charging

BY CHRISTOPHER DAYARAMANI, HEALTH SCIENCES, 2017

**M**obile devices put the world at their operators' fingertips, granting them vast expanses of information and multiple ways to connect with others around the globe. Today, many people take for granted just how much phones are capable of—until the battery dies. However, a team of electrical engineers at the University of Texas, Arlington has found a way to extend the life of mobile devices anywhere in the world, whether near an outlet or out in the wilderness.

Researchers Smitha Rao and J.C. Chao of UT Arlington have focused their team's efforts on the development of micro-windmills with the potential to generate enough energy to power a cellular device. They were able to develop a working prototype, and not long after, they gained the support of WinMEMS Technologies Co., a micro-electrical-mechanical-system manufacturer who agreed to market the technology that UT Arlington will hold the patent on.

"The company was quite surprised with the micro-windmill idea when we showed the demo video of working devices," Rao said. "It was something completely out of the blue for them and their investors." This may be due to the fact that over the last two decades, windmills have been getting larger and larger so that they could generate more and more power. William Pentland of *Forbes* magazine writes that "the typical wind turbine size has grown from about 300 kilowatts in 1990 to a whopping 7.5 megawatts in 2011."

"Rao's designs blend origami concepts into conventional wafer-scale semiconductor device layouts so complex 3-D moveable mechanical structures can be self-assembled from two-dimensional metal pieces utilizing planar multilayer electroplating techniques that have been optimized by WinMEMS Technologies Co," a press release from UT Arlington explained. These micro-windmill are made of nickel alloy, which is extremely durable and can withstand

high speed winds for extended periods of time, tackling one of the biggest problems for MEMS manufacturers. Additionally, Rao and colleagues make the micro-windmills using a batch process, meaning that it costs the same amount to make one or thousand of these mills on a single wafer. This translates to large-scale production of very cost-effective systems.

These windmills are, at their widest point, a staggering 1.8mm. This means that 2,040 of them could fit on the surface of an iPhone 4. The windmills are expected to provide a substantial boost to a phone's battery life in a matter of minutes. Soon, there will be a completely "green" way to keep mobile devices charged nearly anywhere in the world. As of now, this is the only commercial objective that WinMEMS has for these windmills. However, Rao believes that potential applications are endless. Only time will tell what this tiny green energy source could hold in store for us. ■

# Caffeine: A Study Tool Worth More Than Just a Boost

BY CHELSEA CANEDY, BEHAVIORAL NEUROSCIENCE, 2018

**F**rom energy drinks to cups of coffee, caffeine is an asset cherished by students to mentally prepare for the day. But did you know that caffeine can also be used to help remember details? In a double blind study at Johns Hopkins University, scientists examined interesting effects that caffeine can have on long-term memory.

Participants first studied pictures of random objects. They then received either a 200 mg dosage of caffeine or a placebo. Twenty-four hours after the study session, the participants were told to identify images memorized the previous day. Some of these images were identical to those shown the previous day, some had slight differences, and others had no resemblance to the previous images. The participants who received caffeine were more likely to identify the slight differences between images that were similar or identical to those identified the previous day. Though researchers noted this relationship, the caffeine had no significant effect on the number of objects remembered in this study.

Though the impact of this study is significant, these results only occurred when the participant consumed caffeine after studying, rather than before. When the scientists gave participants the same dosage of caffeine before they looked at the images, their recollection of detail was the same as the group that took the placebo. Researchers also found that the amount of caffeine consumed affected the altered memory retention. When given 100 mg of caffeine, participants had no change in memory recollection. When given 300 mg of caffeine, participants began to experience the negative effects of caffeine, including headaches, nausea, and lack of focus. Despite the side effects, these participants showed a slight positive change in memory recollection. The most significant improvement in memory recollection showed in the participants who consumed 200 mg of caffeine; this dosage saw the greatest improvement in memory recollection, with minimal negative side effects.

Though scientists know that the nature of what people remember is a reflection of activity in

the hippocampal region of the brain, it's currently unknown what causes the phenomenon. Some researchers believe that it's caused by caffeine's blockage of adenosine, which can obstruct the expression of norepinephrine. Previous experiments have shown the expression of norepinephrine can increase the consolidation of memories. Researchers also believe that the memory-enhancing effect could stem from caffeine's presence in the cornu ammonis 2, or CA2, region of the hippocampus, which may cause long-term enhancements in the adenosine receptors in this region, thereby strengthening recollection of certain types of memories. Since this discovery is new, and it is still unclear how caffeine causes these changes in cognition, researchers will likely look into how caffeine reacts with these, and other, regions of the brain. ■

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