

# NUScience

Northeastern University's First Science Magazine

## SCIENCE AND SPACE:

From life on Europa to the present state of NASA, there is a lot to consider in this complex and innovative field.

### Also Inside:

- Examining Organic Foods
- Interview with Dr. Gail Begley
- The Ethics of Mass Extinction

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

We meet every **Monday** at **7:30pm** in room **408 Ell Hall**. Come collaborate with us!

## LETTER FROM THE EDITOR

Dear Reader,

NU Science is thrilled to present our first issue of the Fall 2012 Semester. Issue Twelve is of particular significance to me because this will be my first issue serving as Co-Editor-in-Chief, working alongside Mike Murray, as well as the other talented editors, executive board members, and writers that made this issue such a success. Issue Twelve explores a number of current scientific challenges and innovations in a variety of fields. We have chosen to highlight astronomy and space science because of the truly awe-inspiring nature of this field. Humanity's ongoing interest in exploring the mysteries of space dates back to prehistoric times; from Ancient Egyptian astronomy to present day research at NASA, it is evident that the study of outer space has long fascinated mankind. Neil Armstrong put it best when he said, "Mystery creates wonder and wonder is the basis of man's desire to understand." We hope to provide you, the reader, with further understanding of the wonders of space in this issue of NU Science Magazine.

On a personal note, I have been with the magazine since our founding by Kristina Deak in the Fall of 2008. I have sincerely enjoyed watching this publication grow and evolve with each passing semester. Working with our extremely dedicated faculty advisor, executive board, and members each week over the past four years has been a privilege. NU Science Magazine has always been a central part of my Northeastern experience and I am so honored to be able to serve as Co-Editor-in-Chief of this publication in my final year as an undergraduate student.

I am always amazed by the incredible amount of scientific discovery and innovation that captures the interests of our writers and staff with each new issue. I look forward to all we plan to accomplish this year as a group. I could not be more proud of this issue and the intriguing work of the members of NU Science Magazine. We invite you to submit any suggestions you might have on ways we can improve and we encourage you to get involved with the group if you would like to contribute to our magazine. Thank you for reading!

### Elizabeth Gilbert

Health Science and International Affairs, 2013

Co-Editor-in-Chief

NU Science Magazine

## FEEL IN YOUR ELEMENT: TUTORING AND ACADEMIC SUPPORT IN THE COLLEGE OF SCIENCE

BY LAUREN BOEHM, & JESSICA MCINTIRE, BEHAVIORAL NEUROSCIENCE, 2015

**E**veryone loves that moment when something just "clicks." In some classes, however, reaching that point of understanding can feel improbable, if not impossible.

Fortunately, the College of Science offers several different resources that allow students to reach that "Aha" moment.

For students who are struggling with a particular subject, or perhaps just need someone to rephrase a concept, the Peer Tutoring program can help. The Peer Tutoring Program provides an opportunity for students to seek help from peer tutors who have previously taken the class and are capable of explaining the material. The program offers tutoring in a variety of subjects, ranging from introductory level classes to the upper-level electives in Northeastern's core requirements. Peer tutors can meet with students either in groups or during one-on-one sessions. For more information or to request a tutor, students can go to <http://www.northeastern.edu/peertutoring>.

The College of Science Peer Advising Coach program, which started last fall, is an alternative to traditional peer tutoring. The program's goal is to provide a means of one-on-one peer support for students in the College of Science who may be struggling academically or are on academic probation. In weekly meetings, a peer coach focuses on developing successful study, organization, and time management strategies. Rather than working on one course, this program hopes that the involved students will learn how to tackle any subject by building a framework of generalized study skills. So far, the program has had numerous success stories. Any student interested in being paired with a peer coach or being trained to be a peer coach should go to the college of science website under the Academic Advising and Support page. n

# The Life and Times of Dr. Gail Begley

BY HANNAH BIALIC, BIOCHEMISTRY, 2016



**D**r. Gail Begley is an integral part of the faculty within Northeastern's College of Science. Dr. Begley is a cell and molecular biologist by degree, but seems to be a "jack of all trades." She attended Suffolk University where she gained her Bachelor's of Science in Biology along with a minor in Chemistry. She then moved to the other side of town to gain her Master's Degree in Biology with a specialization in Biochemistry, as well as her PhD in Cell and Molecular Biology from Boston University. Now, of course, her heart lies with the Huskies.

Along with her array of degrees, Dr. Begley has also racked up quite a resume. She has served as a teaching fellow in graduate schools, a postdoctoral research fellow at the University of Oxford, a post

doctorate researcher at Harvard Medical School, and a staff scientist at the Marine Biology Lab in Woods Hole, MA. She now serves as a full time faculty member and undergraduate pre-medicine advisor here at Northeastern. Dr. Begley is fully dedicated to giving students the means to gain the education they truly desire. Having majored in biology herself, though never following the pre-med track, she understands the pressures associated with undergraduate sciences and medicine.

Dr. Begley has made quite a name for herself in the world of research. Currently, Dr. Begley teaches a summer research course strictly for undergraduate students and also allows students to work in her lab through a directed study. The topic of her research is bioremediation of hazardous waste sites. She and her team work side by side with bio engineers to understand the "why's" and "how's" of bacteria that eliminate toxins at polluted sites. Dr. Begley's lab focused the purpose of their research through three goals. They first wanted to develop a way to test for the specific bacteria, and they did! They developed a molecular method to detect bacteria by looking for a gene that metabolizes Vinyl Chloride, a main contaminant in such hazardous environments. Vinyl Chloride is a common contaminant of soil and water as well as a carcinogen. Their second goal

was to figure out if the treatment of the bacteria actually decontaminated the site. The answer to this second question was a resounding yes; the bacterial treatment was found to work well in some places, though not all due to the acidic ground and well water of the New England area. In other words, bacteria do not thrive in our conditions. The ongoing research of the project focuses on figuring out more details of the microbial community that Dr. Begley and her researchers discovered. The main question that remains is whether this community can be effective elsewhere or if it is limited to only certain habitats.

Dr. Begley has had two articles published on this topic including an article called, "Oxygen and Ethene Biostimulation for a Persistent Dilute Vinyl Chloride Plume," published in December 7th of 2011.

Dr. Gail Begley is a dedicated and diverse member of the faculty here at Northeastern University; a member we are lucky to have. From personal experience, Dr. Begley does not only look great on paper but she is a truly fantastic professor. She brings a new dimension to class with her debates as well as her interest in service learning. She inspires her students to question all they know in the hopes that they will discover something new. n

## Need to diagnose breast cancer? There's an app for that.

BY KRISTIN MINISH, COMMUNICATIONS, 2013

**W**ant to win \$50,000? Take a trip to the Galapagos Islands? Get a trophy made out of Legos? Intern at Google?

Then it's time to open your computer and start programming. Seventeen-year-old Brittney Wenger of Sarasota, Fla., creator of Cloud4Cancer, did just that.

Wenger was recently honored as the Grand Prize winner at Google's second annual Science Fair. Her computer program, created to aid in the quick and accurate diagnosis of breast cancer, was chosen from over 5,000 international applicants.

Typically, doctors perform fine needle aspirates (FNA) to determine whether a tumor is malignant or benign. FNAs, however, are one of the least precise diagnostic tools available. After witnessing the pain of family members affected by the disease first-hand, Wenger saw a critical need for a program that could improve early detection rates for a disease that affects 1 in 8 women.

Cloud4Cancer is an artificial neural network modeled after and programmed to think like the brain. It can detect patterns far too complex for humans or other types of software. The online app allows doctors

to enter results from non-invasive biopsies into the designated fields. Cloud4Cancer then analyzes the results and determines whether or not a person has cancer.

After running over 7 million tests, using more 700 test samples, Wenger found that her app correctly diagnosed 94 percent of cases and correctly identified 99 percent of malignant tumors. This extraordinary accuracy is only expected to increase as more test samples become available. Wenger hopes the software will be hospital ready by March 2013 and can eventually be applied across many technology platforms and disease areas.

While winning awards is nothing new for this teenage genius, this most recent win has not only validated her research, but also created some tremendous opportunities.

Wenger has been working with artificial intelligence since seventh grade and plans to pursue a degree in computer science. Her dream is to become a pediatric oncologist.

Her lesson for us? Never outgrow the "why" phase and never, ever give up. n

Photo courtesy of 99healthplus.com.



# The Real Differences in Organic Food

BY JESSICA MCINTIRE, BEHAVIORAL NEUROSCIENCE, 2C

Over the last few years, organic foods have gained popularity to the point that grocery stores like Whole Foods and Trader Joe's have specialized their merchandise to appeal to people choosing to go organic. Magazines, celebrities, and nutritionists have endorsed the movement. And in fact, the organic produce market has increased by 12 percent in just the last year, making it a \$12.4 billion industry. While some buy into the idea of organically produced foods, others continue to express skepticism – is it really a healthy eating choice, or is it a marketing scam to convince consumers to pay more for their foods? Dr. Dena Bravata at Stanford has recently published a paper addressing just that issue.

In a meta-analysis of over 200 previously published studies on organic food quality, Dr. Bravata found some results that have the clean eating world in a tumult: On average, organically grown foods are no more nutritious than conventionally grown counterparts, and are no less likely to be contaminated with E. coli. So then does this debunk the supposed benefits of organic foods? Not necessarily.

To be deemed organic, foods must be produced following a strict list of federal guidelines. Foods grown organically cannot come into contact with synthetic pesticides, hormones, fertilizers, ionizing radiation, or sewage sludge. Soil used to grow organic foods must be improved using crop rotation, cover crops, and animal or plant substances like compost.

Organic livestock, in turn, must be fed with organic agricultural products without additives like growth hormones or antibiotics. The treatment of organic livestock is also regulated, ensuring that the animals receive sufficient nutrition, appropriate housing and sanitation, exercise, year-round access to the outdoors, clean water, direct sunlight, opportunities to graze, and enough space so that they do not experience competition for food or overcrowding. In short, a livestock animal raised organically has been treated in a manner that provides the animal maximum welfare with minimal stress.

The effects of these regulations were evident in Dr. Bravata's study. While pesticide residue was present in 38 percent of conventional produce, it was only detected in 7 percent of organically grown foods. The small percentage present in organic produce is presumably from unavoidable contamination from neighboring farms, even though organic crops are required to have runoff deterrents to prevent this.



Additionally, conventionally produced pork and chicken were more likely to be contaminated with antibiotic-resistant bacteria, which is a product of the mass-administered antibiotics in conventional feed for livestock. These bacteria should be killed during cooking, but still, if the food is cooked improperly, it could cause a very bad case of food poisoning untreatable by antibiotics. And while for the most part conventionally grown foods were equivalent in nutrition, there were a few exceptions. Phenols, a biological chemical believed to prevent cancer, were one of these. Another, Omega-3 fatty-acids, which benefit the heart, were more prevalent in organically produced milk.

So what does this say about the health benefit of eating organically produced foods? If a consumer's main concern is nutritional value, buying organic probably is not worth the additional cost. However, most people who eat organic choose to do so not because they believe they are getting better nutrition from their food, but rather because of the absence of harmful pesticides, growth hormones, genetic modifications, and other additives. Those who go

organic like to know about where their food comes from and the processing it goes through before it gets to their table. Dr. Bravata agrees that this is a legitimate concern.

But conventionally grown produce has its own set of restrictions that protect consumers from dangerous products. In fact, while more than a third of conventionally grown produce contained pesticide residue, Dr. Bravata found that it was almost always within safe levels. Does this mean that while organic food might be less polluted, there is no health risk to eating conventional foods? Beth Reardon, a nutritionist in the Duke University Health System, believes that this possible risk to our health is what actually needs to be assessed. She points out that we may not yet understand the full extent of the health risks of eating conventionally produced foods. It takes two generations for environmental effects to be detected in our genetics, but most studies about organic foods only span a two year period, and therefore we cannot begin to understand the far-reaching effects of the environment on our health. n

# One Man's Junk, Another Scientist's Treasure

BY DAVID ADAMS, CHEMICAL ENGINEERING, 2017

Almost a decade of research and the combined efforts of over 400 scientists working on the Encyclopedia of DNA Elements (ENCODE) project has led to an entirely new viewpoint on our DNA. Within the human genome there are over 20,000 genes, the segments of DNA that provide instructions for creating proteins that affect every aspect of what makes a person unique. Considering their importance, it's easy to see why scientists have focused so much attention and resources on studying genes. Yet despite their vast number, genes are dwarfed by the rest of the double helix structure that the genome takes. In fact, genes comprise less than 4 percent of human DNA. When scientists discovered this in the 1970s, they swept the huge non-coding part of the genome under the carpet, classifying it under the umbrella of "Junk DNA."

One of the prevailing ideas until recently was that the majority of our genome is evolutionary leftovers, pieces that were once useful but have lost purpose in the long history of human evolution. The ENCODE project has put that theory up for a major reexamination.

Findings from ENCODE research show that large parts of the non-coding DNA are involved in regulating all-important genes, controlling the extent to which they are expressed or if they show up at all. In previous years the common scientific concept of DNA has been like a desert, with a few oases of activity amongst a desolate landscape. In an interview with Scientific American, computational biologist Ewan Birney said that a better metaphor was "a jungle—a completely dense jungle of stuff that you have to work your way through." In other words, the genome works like a vibrant ecosystem; a change in one area affects everything else. In the same interview, Birney predicted, "In this century, we will be working out how humans are made from this instruction manual."

The functions of non-coding and protein-coding sequences of the genome are complexly layered. Yale University DNA researcher Mark Gerstein said, "It is like opening a wiring closet and seeing a hairball of wires." Some sections of non-coding DNA aren't in close proximity to the genes they affect, making it difficult to understand the mechanisms behind how DNA functions. Not being in "close proximity" is a relative term, however, when working on the molecular scale. A double helix structure allows a molecule over three feet long to be wrapped around itself into a length of about three nanometers. ENCODE is steadily uncovering the mysteries of this compact structure.

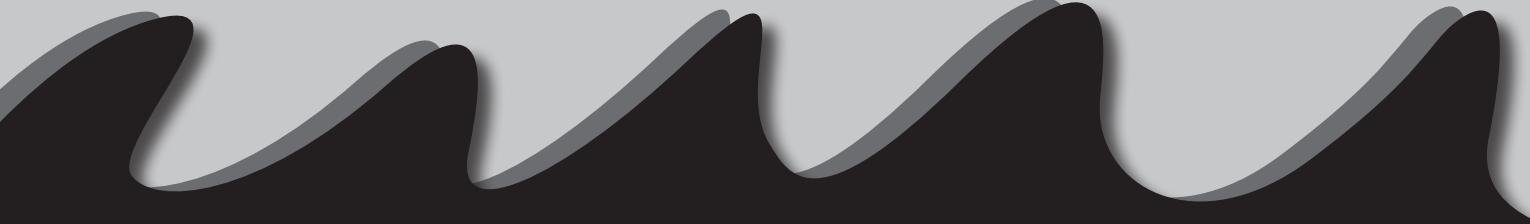
Any information on the workings of human biology is welcome, but many people are wondering what sort of actual advances in technology or medicine might this research have. Many geneticists point out that understanding the genome helps pinpoint the molecular basis of many horrible and devastating illnesses.

For instance, researchers at the Pittsburgh University School of Medicine are currently looking at treating the crippling disease of rheumatoid arthritis with gene therapy. The university's staff geneticists and biochemists are treating sufferers of the disease who require joint transplants. The tissue placed into the patient during surgery contains genes that code for proteins which alleviate swollen joints, fatigue and pain that rheumatoid arthritis causes. Already links have been found between changes in our non-coding DNA and genes related to illnesses like Crohn's, multiple sclerosis, lupus, celiac disease, and even some cancers. Gene therapies that affect the non-coding parts of DNA could lead to cures that some have given up hope on.

Despite the conclusions that many scientists have drawn from ENCODE's research, the question still remains as to whether our DNA holds any amount of "junk." Experts in the field such as Howard Hughes Medical Institute Biologist Sean Eddy still believe it does. In a paper Eddy wrote, he said, "Genomes are made of repurposed sequence, borrowed from whatever happened to be there, including the 'junk DNA' of invading transposons." Eddy explains in the same paper that evolution appears to be an imperfect process. As the human genome mutates and changes over time, it doesn't nicely clear out all the unused segments. They are recopied over and over between generations. Other parts are inserted from viruses or other unwanted occurrences. These segments are referred to as transposons.

Perhaps scientists really can separate out the treasure parts of our DNA from the cluttered junk, or maybe that garbage is just laying around waiting for renewed purpose. Researchers from the ENCODE project and elsewhere are continuing their research deep into the functioning of the human genome to find out. n





# *Into the Abyss: Why We Don't Know What Is Really Down There*

BY KATHERINE HUDSON, MARINE BIOLOGY, 2017

When one thinks of the darkest places on the planet, what comes to mind is the demonic angler fish (order Lophiiformes), seen in the most recent Disney movie to be rereleased in 3D, Finding Nemo. Because of the environment they live in, many deep ocean organisms are similar to this broad category of fish, characterized by small eyes, dark coloration, and the ability to produce their own light (called bioluminescence) for a large variety of purposes, including hunting.

One such creature of the deep is the black dragonfish (*Ildiacanthus atlanticus*). The black dragonfish, like angler fish species, has small eyes, large teeth, and is bioluminescent. The dragonfish can be found in waters south of the equator at depths of 2000 meters. They prey on small fish using their abundant bioluminescent photophores (light producing organs) to attract their prey. Using photophores attached to a beard-like extension, known as a chin barbel, the black dragonfish is able to lure in small prey fishes.

Angler fish and black dragonfish are also similar in the fact that they exhibit sexual dimorphism, meaning that one gender is significantly smaller than the other. In the situation of these two species, the female organism is the larger of the two. The female dragonfish can reach lengths of 40 centimeters (approximately 16 inches), have teeth similar to fangs and chin barbels. In contrast, males are only 5 cm (or 2 inches) in length. They also lack teeth, chin barbels, and a functional digestion system. To breed, the males become testicular parasites, and attach to the females. They lose all the organs they have except for those required for reproduction.

Are there other organisms like these in the darkness of the ocean? What other cool things can deep-sea creatures do? The answers to these

questions are unknown because the distance between these organisms and the people that want to study them is vast. As water depth increases, water pressure increases. At a depth of 2000 m, where the black dragonfish is found, the pressure is 200 atmospheres, the equivalent of 200 times the air pressure experienced at sea level. The organisms that live at great depths have adapted to this immense pressure so when scientists bring them up to the surface to study, they die.

Water pressure also causes problems when scientists try to travel to the organisms. Due to the immense pressure, humans cannot dive down directly to visit these ecosystems without being crushed in the attempt. People, however, have traveled to these depths in submersibles. One of these vehicles, Alvin, based in the Woods Hole Oceanographic Institute in Woods Hole, Massachusetts, has made more trips to the depths of the ocean in fifty years than any other submersible of its kind and is capable of diving to 4,500 m. Alvin has made many discoveries including hydrothermal vents, black smokers, and cold seeps in the past few decades, but because of its age, is due for an upgrade. Out of commission since 2012, Alvin's new upgrade will include reconstructing it around a five ton titanium sphere with a diameter of 2.2 meters, which will allow the submersible to travel to depths of 6500 m.

Every upgrade, however, comes with a price tag. The new passenger sphere alone costs \$11 million dollars to construct. In total, the redesign of the submersible costs \$40 million. With the full advantages of the reconstruction not available for another three to five years, the United States is falling behind countries like France, China, Russia, and Japan who have designed submersibles to travel below 7000 m. The current state of the economy is

not helping, forcing the President to cut off funding to new submersible construction in Hawaii and other assets in deep-sea exploration. With this lack of funding, how are scientists supposed to explore the depths of the ocean?

Robert Ballard, veteran deep-sea explorer and discoverer of the HMS Titanic, says that the future is in remotely operated vehicles (ROVs) and autonomous underwater vehicles (AUVs). These robots can either have cameras or data equipment attached to them, allowing scientists to indirectly observe the environments they are studying and cutting the costs of large ships and crews associated with human operated vehicles (HOVs) like Alvin. Ballard himself used Alvin to discover the hydrothermal vents but now sees HOVs as a "dead paradigm." Ballard said, "AUVs augmented with ROVs is where I see the future. I don't need any people in them."

Technological advances improve AUVs and ROVs every day. ROVs are able to spend days underwater and AUVs are able to spend months recording data. Alvin is limited to a few short hours of collection, an even shorter amount of time when travel is accounted for. Cords are now being developed for ROVs that are only three times the width of a human hair, allowing them to dive deeper and complete more missions. These technologies are not perfect, however, and still lack the funding to help perfect them. Without financial support, ROVs and AUVs alike sit and wait until such a time when they can be put to use. □

# The Brain in Our Stomach

BY SHANNON MURPHY, BEHAVIORAL NEUROSCIENCE, 2015

Ever feel like your stomach has a mind of its own? You may be right. Scientists studying what some have dubbed "a mind-body connection" have gone as far as to label the stomach as the body's "second brain". Research shows the stomach can not only act without direction from our brain, but also transmit signals back that affect emotion, decision-making, and even learning.

According to The brain-gut interaction: the conversation and the implications, a study published in the South African Journal of Clinical Nutrition, about 90% of the communication between the brain and the gut is from the gut to the brain.

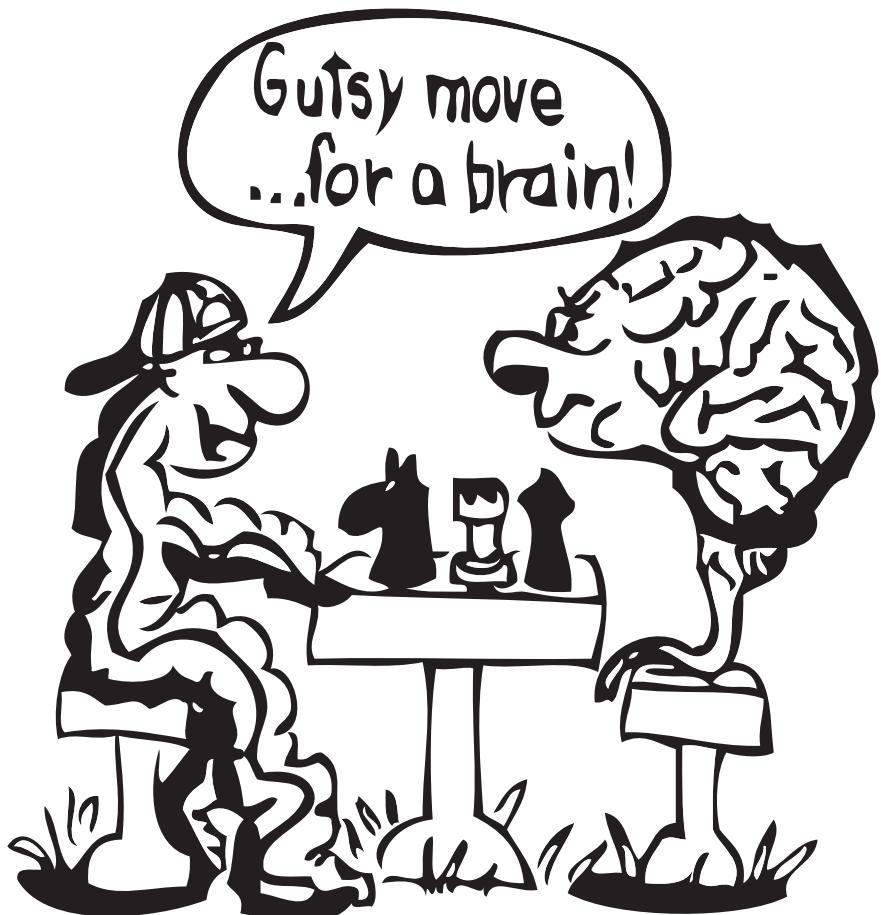
This "second brain" – the enteric nervous system (ENS) – is made up of over 100 million neurons. That's more than the spinal cord or the peripheral nervous system. In other words, the physiology of the stomach is quite sophisticated. Actually, it is the only organ that can operate independently of the brain.

## Serotonin and the Gut

Many are surprised to learn that in addition to 30 other neurotransmitters, serotonin is used in the gut. Actually, the bowels utilize 95% of the body's serotonin. This could be a reason why people who take selective serotonin reuptake inhibitors (SSRIs), a class of compounds used as antidepressants, often experience gastro-intestinal (GI) side effects. Patients Irritable Bowel Syndrome (IBS) are now found to have extra serotonin built up in their intestines. Researchers are also looking at the relationship between serotonin from the stomach and autism. Autistic people tend to have elevated levels of gut-produced serotonin in the blood as well as GI issues. Whether this means autism causes abnormalities in the gut or the gut somehow causes or worsens symptoms of autism has yet to be determined.

## Food and the Brain

New research on the ENS has led to developing views on our eating habits. In *Fatty acid-induced gut-brain signaling attenuates neural and behavioral effects of sad emotions in humans*, a group of Belgian researchers found that different components in foods have a direct effect on neurohormones in the gut that signal the brain. They fitted volunteers with nasogastric tubes to deliver foods to their stomach, bypassing the pleasurable aspects of consuming sustenance. Though the volunteers did not know if they were given fatty acids or a saline solution, those given fatty acids were found to have both sad feelings and hunger sensations reduced by about half, compared to the saline solution. Taste aside; what you eat has an effect on your mood.



*Photo courtesy of entericnervoussstem.webs.com*

## Evolutionary Basis

When animals were first developing, one of the most important body processes was digestion. Therefore, the first nerves were created in the intestines and were the beginnings of the ENS. Later, as animals became more complex, the brain developed separately along with the spinal cord. Both "brains" develop from the same tissue, the neural crest, during fetal development and are loosely connected by the vagus nerve.

## The second brain and health care

While psychiatrists and other professionals look to the brain for an understanding of mental health care issues, scientific study is also leading them to better "digest" how the "second brain" is another source of many neurological concerns. I hope to see more research being done on the ENS and ultimately

application in a clinical setting. We have only just scratched the surface in our understanding of the ENS. I believe that with more research, the ENS could become a powerful tool to help us diagnose and treat a large range of symptoms and diseases in multiple areas of medicine. n

# Diagnosing Psychopathy in Children

BY LAUREN HITCHINGS, BIOLOGY, 2015



Most children one encounters at a schoolyard or a playground are happy, loving, and playful. They may have moments in which they are shy, selfish, or impulsive; however, for the most part they smile and exhibit an innocent demeanor as they develop and learn about their world. But imagine a child who is instead disturbed, cold, manipulative, and often violent. This child does not respond to rewards or punishments, and is calculating and cruel. Are the parents to blame for the behavior? Is the child just being moody, or going through a phase? Or is it possible that the child is in fact a psychopath?

Psychopathy is a recognized personality disorder that is estimated to have about a little less than 1% prevalence in the adult population. A formal diagnosis in adults is rare outside of criminal cases. It is almost unheard of to diagnose a child as a psychopath. It is complicated and often controversial to diagnose a child or adolescent with the disorder, due to difficulty defining personality traits and recognizing symptoms in children, and the ethical concerns over labeling a child a psychopath.

Adult psychopathy is defined by stable personality traits such as being arrogant, deceitful, manipulative, and shallow. Psychopaths cannot establish emotional

relationships and they lack the capacity for emotions like empathy, anxiety, and guilt. They are exceptionally impulsive, irresponsible, and prone to criminal behavior. To be diagnosed with the disorder, these tendencies to think, perceive and act in certain ways must occur long-term and remain stable over time. Even in adults, psychopathy can be difficult to diagnose and is measured on a spectrum. The most reliable and accepted tests are psychopathy checklists called PCL and PCL-R. In these tests, a scoring system is used and several ranges denote types or levels of psychopathy. There is also research that demonstrates neurological abnormalities in psychopaths, including underdevelopment of certain areas and irregular brain activity in regions associated with learning from mistakes, emotional processing, and moral decision making. Some research has also indicated possible biochemical abnormalities.

Understanding how psychopathy may present itself in children delves into incredibly blurry territory. Personality disorders do not have a sudden onset in adulthood; however, it's unclear exactly when legitimate symptoms first develop. Many of the defining traits of a psychopath, such as arrogance, impulsiveness, or antisocial behavior are often normal

parts of child development. One of the critical traits in deciding whether a child is a "fledgling psychopath" is being "callous-unemotional". Callous-unemotional children tend to be incredibly manipulative, and often lie or hold extreme grudges without reason. They do not respond to punishments or shame and will do anything to get what they want, even if that means being cruel or hurting others.

Studies since the 1970s have revealed that almost every adult psychopath had been incredibly antisocial as a child, yet almost half of children who scored high on measures of antisocial qualities did not go on to become psychopathic adults, indicating that early test scores are necessary but not sufficient in predicting adult psychopathy. A particular study which tracked the psychological development of 3,000 children over 25 years found that signs of psychopathy could be detected in children as young as 3. Callous-unemotional behavior can be linked to anatomical differences in adolescents, indicating that traits are likely innate and genetic in origin in most children. However, some callous-unemotional children develop into adult psychopaths while others do not.

Even if there were a way to confidently label a child as a psychopath, there is still an ethical issue at hand. Labeling a child a psychopath has a strong negative connotation, and could lead to discrimination by teachers, psychologists, or under the judicial system. The parents of a psychopath do not receive the same sympathy or support that parents of children with less stigmatized personality disorders like autism or ADHD do. Finally, and most crushingly, a diagnosis of psychopathy is thought of as a life sentence; totally untreatable.

According to Mark Dadds, a psychologist at the University of New South Wales studying antisocial behavior in children, "[t]he research showing that this temperament exists and can be identified in young children is quite strong." A small yet growing number of psychologists, including Dadds, believe that confronting the problem early enough may allow these children to change their course and develop more normally. Despite the difficulties in formally diagnosing a child with a severe personality disorder, their hope is that the capacity for empathy and emotional connections, controlled in specific regions of the brain, may still be weakly present in callous-unemotional and psychopathic children, and could be strengthened with proper treatment and therapy. n

# Is violence determined by your genes?

BY JESSICA MELANSON, JOURNALISM, 2014



After Bradley Waldroup's October 2006 arrest in Tennessee for one completed and one attempted murder, the case seemed open and shut to prosecutors. Waldroup had confessed to the brutal acts: He had shot his wife's friend eight times and then took a machete to his wife as she tried to leave with their children. There was no question of his guilt.

But the verdict shocked prosecutors. Instead of conviction on capital offenses, Waldroup was found guilty of lesser charges not punishable by death. He was ultimately sentenced to 32 years in prison.

What swayed the jury was a defense pointing to physical aggression as a part of Waldroup's very genetic makeup. Waldroup had a gene that led to low Monoamine oxidase A levels in his brain.

Monoamine oxidase A, known as MAO A, is an enzyme that breaks down neurotransmitters such as dopamine and serotonin in the brain. The body's amount of MAO A enzyme is regulated by a gene of same name. Several studies since the 1990s correlated low levels of MAO A enzymes with predisposition to aggressive behavior, drawing the colloquially named "warrior gene" into mainstream and controversy.

"Warrior gene" research picked up after a study found a Dutch family whose male members were all violent criminals (arsonists, rapists, attempted murderers) had low MAO A levels. This hinted at a

genetic link between physical aggression and deficient MAO A levels.

A December 2006 study in *Aggressive Behavior* compared the behavior of two different kinds of mice, one with a non-functional MAO A gene and one with a functioning MAO A gene. Different comparative experiments included introducing a cricket or a different kind of (heavily anesthetized) mouse into the same cage as the subject mouse. A final test compared the mice's behavior after six weeks of isolation when a second mouse was introduced to the subject mouse's cage.

It took the mice with the non-functional MAO A gene less time to attack crickets and fellow mice after social isolation than subject mice with functioning MAO A genes. After introducing a different kind of mouse to the cage, MAO A-lacking mice exhibited less interest in investigating the anesthetized mouse than mice with normal MAO A levels. Scientists concluded that MAO A-deficient mice are more prone to aggression and less to "social investigation" than mice with normal MAO A levels.

A 2007 study published in the PLoS open-source research journal investigated the effect of untreated early childhood trauma on people with the "warrior gene." Researchers had a mix of mental health outpatients who reported early childhood traumas and healthy volunteers fill out questionnaires to self-report aggression levels.

The results indicated the gene leading to low MAO A and exposure to early trauma presents a "significant risk factor" of aggression in adulthood for men. Simply having the gene is not what triggers greater physical aggression; instead, the combination of the gene and untreated psychological effects of childhood abuse can lead to aggression during adulthood.

This link is exactly what Bradley Waldroup's defense attorneys hinged their "warrior gene" defense upon: that Waldroup had both low MAO A levels and that he suffered childhood emotional trauma. Waldroup's lawyers were so convincing that the jury returned a reduced verdict. Said juror Debbie Beaty to NPR, "A diagnosis is a diagnosis, it's there. A bad gene is a bad gene."

Prosecutors, on the other hand, called it junk science, because "correlation" is easily twisted into something more definitive. The science is hugely controversial, especially as race enters the mix. In the first place, the "warrior gene" gets its name from its prevalence in warfare-prone populations. About two-thirds of violence-prone ethnic groups have the "warrior gene," while only about one-third of Western populations do.

Scientific American blogger John Horgan challenged the science in a 2011 post. He wrote, "Obviously, the warrior gene cannot possibly live up to its name. If it did, the whole world ... would be wracked by violence. The warrior gene resembles other pseudo-discoveries to emerge from behavioral genetics, like the gay gene, the God gene, the high-IQ gene, the alcoholism gene, the gambling gene and the liberal gene."

Horgan went on to reference another well-known 2009 study by Brown University researcher Rose McDermott, "Monoamine Oxidase A Gene (MAOA) Predicts Behavioral Aggression Following Provocation." McDermott found MAO A lacking individuals are more aggressive. Her findings dominated that news cycle and landed her on a special "warrior gene" centric episode of Dr. Phil. But Horgan called McDermott's results inconclusive: The number of people lacking MAO A who displayed aggressive behavior was only 7 percent higher than the number of those with normal MAO A levels who displayed aggressive behavior.

Horgan also brought up the potential to abuse the research, citing Waldroup's reduced verdict as a prime example. Horgan is among many scientists and non-scientists alike who object to the research.

In the haze of uncertain research and findings easy to manipulate and abuse, only one thing is for sure: The jury's still out on this one. n

# A Chat With Northeastern's Iceman



BY ANDREW BLOY, BIOLOGY, 2016

Throughout the school year, Professor Detrich can usually be found teaching a class or doing research in a lab. However, over the summer, Professor Detrich can be found braving the icy waters of the Southern Ocean, studying the biologically unique icefish. These fish are unique in that they do not make red blood cells. NU Science was lucky enough to be granted an interview with Professor Detrich, or the Iceman, as his students affectionately know him.

**NU Science:** Can you tell me a little bit about your educational background?

**Prof Detrich:** Sure. I went to college at Case Western Reserve University in Cleveland, and while I was there, I took a very extended science stem curriculum. I became a little disenchanted with the idea of becoming an engineer so I decided to get my degree in psychology. I originally planned to become an experimental psychologist and study learning but during my senior year I decided that I needed some introductory biology, so I took Principles of Biology 1. I was fascinated by the inner-workings of the cell. At that time, the genetic code had just been cracked; it was all very new and novel. However, I had already been accepted to Yale University in the psychology program. One of my principle professors who was a graduate of Yale got the graduate coordinator in Biology to take a look at my file. I was accepted into the biology program with the equivalent of 8 semester hours of biology.

**NU Science:** Scientifically, what are your interests?

**Prof Detrich:** Over the years as my career progressed, my interests have changed and I have recently become interested in the process of development of multicellular organisms. I have also been working with Antarctic Fish to study how organisms live in extreme temperatures. I've also become increasingly interested in how the biosphere is going to change as the climate warms.

**NU Science:** How do you feel about teaching?

**Prof Detrich:** I think that I have the best of both worlds here at Northeastern. I spend about 40% of my time teaching, 50% of my time doing research and 10% of my time doing service. I would not be

comfortable only doing research; I value contact with students and I try to be as good a professor as I can for them. My goal is to inspire; I want all of my students to go out and achieve their goals and I am here to facilitate that. Sometimes I describe myself as a coach in the classroom because the hard work has to be done by the students, but if I can direct and guide, provide and organize a plan of action, I believe that will help. However, if I was only teaching, I would not get to share the new ideas that are coming in every day from research with my classes. That is one way that I think I can get students excited about new concepts.

**NU Science:** Now, a big portion of your research centers around the icefish of the Antarctic- would you be willing to share?

**Prof Detrich:** One of the most interesting creatures in my mind on the planet are the fish that belong to the icefish family of Notothenioid fishes. They are unique in that they do not make red blood cells, they don't make hemoglobin or even have an oxygen carrier protein. All other fishes, roughly 25,000 species, have red blood cells, but these 16 species of icefish don't. They have lost the capacity to make a component of the body that is nearly synonymous with being a vertebrate. So yes, this has been the focus of my work for some time. I have been working on the blood system for about twelve years and working on the fish in general since 1983.

**NU Science:** So I also understand that Icefish have decreased bone density and the fact that the icefish don't make red blood cells can prove valuable to medical research; can you tell me a bit more about that?

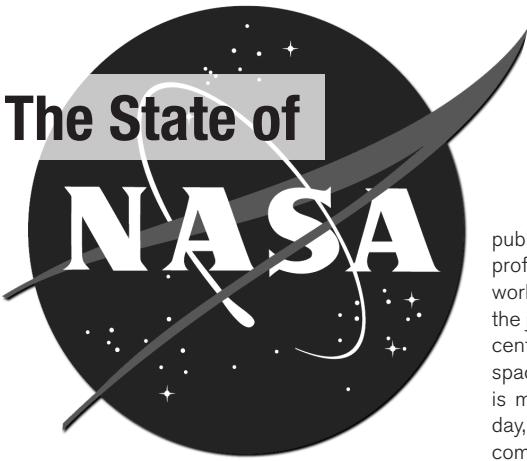
**Prof Detrich:** Let's take anemia first. The icefish aren't producing red blood cells so it is possible to take the organ where red blood cells are made, in fish that is often the kidney, and combine the genetic material from a red blooded species and the genetic material from the kidney of a white blooded fish. Because of the complexities of nucleic acids, we can subtract out all the common components and find the genes that are expressed exclusively in the red-blooded species. These are potentially genes involved in making red blood cells. Ultimately the

hope is to provide targets for therapeutic intervention and the treatment of anemia.

The low bone mineral density of these fish is also very interesting. From what we understand, 50 million years ago, the ancestor of the icefish was heavy boned. Roughly 34 million years ago, the oceans around Antarctica cooled, and now it is down to the freezing point of saltwater (-1.9 C). These fish have evolved to living in cold conditions for a very long time and they have evolved some very novel capacities, one of which is the antifreeze protein which prevents their bodies and tissues from freezing. Because the cooling chased away most of the temperate fishes, there were many ecological niches for icefish to exploit. But because the early icefish were heavy boned and lacked a swim bladder, a common feature in most fish used to regulate buoyancy, they found it difficult to leave the benthic zone or bottom of the sea, to go get food. So, lacking a swim bladder, you can make your body lighter in a couple of ways: one of these ways is to decrease the density of your bones and the other is to accumulate lipids. The icefish have actually done both. The key here from a health perspective is that we have an adaptive feature in the icefish, low bone mineral density that corresponds to a disease in humans. Yet the fundamental processes that underlie the deposition of calcium in bone are the same. So if we can find what the critical changes are that lead to the low bone mineral density of the icefish, perhaps we can turn that into a therapeutic intervention for osteoporosis.

**NU Science:** When you are not teaching or doing research, what do you like to do in your free time?

**Prof Detrich:** I have two hobbies- one of them is flying gliders, which is challenging when trying to fly for high and long distances without the aid of a motor. I've flown to 18,000 feet, as long as 5 hours, and for several hundred kilometers. My personal goal is flying high. I like to see the beginnings of the blackness of space and the curvature of the Earth. My other hobby is photography, which I can actually combine with gliding. n



BY JOSEPH ZIMO, MECHANICAL ENGINEERING, 2015

**O**n October 11th, 2010, President Barack Obama signed a bill that will put astronauts on an asteroid by 2025 and on Mars by the 2030s. In mid-2011, however, NASA's Space Shuttle program was retired. What does this mean? Is the United States abandoning space research? Quite the opposite, actually. The cancellation of the Space Shuttle program means that NASA will no longer be responsible for ferrying astronauts to and from the International Space Station. This responsibility, for the short term, will fall to European, Russian, and Japanese space programs and then, once deemed appropriate, to private American companies.

Now that NASA no longer has to act as a taxi-service to space, they are spending more time focusing on a mission statement of exploration and discovery. A focus that many people, including President Obama, believe to be more worthwhile. The rover on Mars, Curiosity, is an example of a post-shuttle cancellation project. The probe Juno is expected to arrive at Jupiter in 2016, and the Dawn is scheduled to arrive at the dwarf planet Ceres in 2015. In addition to probes, NASA has plans to build a multipurpose crew vehicle and a heavy-lift launch vehicle with the capabilities to bring astronauts to Mars and sustain a mission for an appropriate length.

With NASA focusing on science and research, private American companies will be able to focus on what they do best, making money. There has been staunch opposition against allowing separate entities to shuttle astronauts into low orbit. The chief concern is that of safety, but NASA has assured the public that the independent spaceflight companies will be held to very strict guidelines and regulations. Many of these contracted companies, such as Boeing and Virgin, already have very solid aeronautic and aerospace experience. However, other lesser-known companies like XCOR Aerospace and Blue Origins have the daunting task of not only proving their work is solid, but also proving that it is superior to that of companies who are already flying passengers around the world.

The transfer of the shuttle program to the private sector will have a substantial effect on

public access to sub-orbit. There has to be a large profit involved for these programs to succeed and work is being done on monetizing every aspect of the journey. If all goes as planned, by the turn of the century, there could be thousands of people living in space. Even today, the International Space Station is manned with a crew of six people, 24 hours a day, seven days a week. With the introduction of commercial space stations, it will not be long before people are not only living in space, but also working to maintain and service the stations. This space tourism is a real venture being taken very seriously. Hotel tycoon Robert Bigelow is one of many working on developing commercial space stations in low orbit.

But what if there won't be enough interest? It may be too expensive, it may be too dangerous. The list of reasons why it could not work is extensive, and yet progress continues. On May 26th SpaceX succeeded in completing the first commercial docking to the International Space Station. For \$200k, you can secure a seat on Virgin Galactic's first commercial space flight and be among the first 1000 people in space. Space tourism is accessible, and slowly becoming more affordable.

If the profits of space tourism aren't enough to fund such expensive ambitions, other possible ventures remain. Planetary Resources is one company researching the means to mine asteroids. The resources could be used for any number of applications; from rare metal sale or microbial life research to building materials for orbiting spacecraft or colonized bases. Shackleton Energy Company is researching moon mining and plans on establishing "refueling service stations" in space. That's right, gas stations in space.

With NASA focused on exploration and discovery, and private enterprises exploring all manner of opportunities, it isn't hard to imagine these new industries taking off. The Curiosity rover made big news recently, but don't think that the innovation will stop there. As technology develops, humans will continue to travel, explore, and learn about the universe we, perhaps prematurely, call our own. n

# Neil Armstrong

BY BRENT KISBY, BEHAVIORAL NEUROSCIENCE, 2015

**N**eil Armstrong is known to the world as the first man to step foot on the moon, but he has done so many other things in addition to this impressive accomplishment. Neil Armstrong was born in Wapakoneta, Ohio on August 5, 1930. He received his Eagle Scout award, the most prestigious award given to Boy Scouts, in 1945. At the age of 17 he entered Purdue University, where he studied aerospace engineering for two years. He then went into the Navy as a naval aviator until 1952. There, he served on the National Advisory Committee for Aeronautics (NACA) until he left the Navy in 1955, to finish his degree in aerospace engineering at Purdue. Neil Armstrong made a very successful career early on with the newly formed National Aeronautics Space Administration (NASA), where he worked as a test pilot. He also managed the Gemini project, the precursor to the Apollo missions, in the 1960s. During the Gemini project, Armstrong was promoted to astronaut status.

Neil Armstrong gained national and international recognition as the first man on the moon. The Apollo program was NASA's attempt to put a man on the moon before the Russians were able to do so, a competition driven by increasing Communist pressure during the Cold War. The Apollo 11 mission, commanded by Neil Armstrong, was the first manned NASA mission. The other astronauts were Buzz Aldrin and Michael Collins. On July 20, 1969, the moonwalk was aired on national television. Neil Armstrong famously phrased the words, "One small step for man, one giant leap for mankind." Those words will be carried throughout time as a fundamental moment in world history and one of the most significant moments in science. Neil Armstrong and his Apollo 11 crew accomplished what was previously considered the unthinkable, a wonderful endeavor for science and humanity.

After a rush of fame and recognition, Neil Armstrong went on to live a very modest life in consulting and academia. He got his masters degree in Aeronautics from University of Southern California before becoming an associate professor of aeronautics at the University of Cincinnati. In 1986, he was tasked with the investigation of the Challenger disaster, in which the entire crew died in the explosion.

Armstrong never shied away from the idea of space exploration, yet he stayed away from the public eye. In 2010, Neil Armstrong reached out to Congress and President Obama, encouraging them to not cut funding for the Constellation program, which plans to send a man to the moon. He was a huge proponent for space exploration and space education, and a very modest man. The scientific community will miss such a great scientist and explorer. n

# On the Matter of Dark Matter

BY BILL FLEMING, CHEMICAL ENGINEERING, 2016

Albert Einstein was the first person to reason that "empty space" may not be a vast emptiness, but rather, something more significant. The next logical question to ask would be, "what exactly is it?" Although no statement can be made definitively as of yet, Einstein did have a few ideas, one of which he published in one version of his gravity theory. In this theory he discusses something called a cosmological constant which implies that space can possess its own energy, and that as the universe expands and more space is created, more of this energy would be created along with it.

Unfortunately, more is unknown about space and the universe's expansion than is known. Its composition has, however, been deduced. Currently many astronomers believe that the universe is composed of "dark energy," that is, the energy that Einstein's cosmological constant refers to, "dark matter," and the matter that most people understand and see every day. The current numbers are 70% dark energy, 25% dark matter, and 5% matter.

These numbers came from rotational constants that can be observed. These constants can then be used to estimate the amount of matter we should be able to see, and when compared to the amount we do see, this results in the numbers of 5% matter and 25% "dark" matter. When looking at an individual galaxy, you can measure the rate at which individual stars rotate about the galactic center of rotation. The curve that is formed is related to the distribution of matter in the galaxy. What has been observed is that the stars on the outskirts of the galaxy seem to rotate too quickly. This implies that there is more matter in the galaxy than is accounted for. In fact, we would need to see about 5 times more matter than we do, via electromagnetic radiation.

So what exactly is the dark matter that makes up one quarter of our universe? This is not a simple question to answer, and it's because what has been deemed dark matter is the "stuff" that is supposed to be there but isn't. In the simplest of terms, it is matter that has somehow managed to hide from some of the brightest minds available. For these reasons, it is easier to define it in terms of what it is not, rather

than what it is. We know that it is not planets or stars that we can see. That much is already clear, since the planets and stars do not account for the missing 25%. Second, it is assumed that it is not matter in the form of dark clouds. Matter is made up of particles called baryons. The reason it is believed that dark matter cannot be baryonic clouds is because baryons absorb radiation, and this is something that makes them detectable. Another thing that dark matter simply cannot be is antimatter. This is because when antimatter and matter come in contact they destroy each other, generating gamma radiation, which again would be detectable. Finally, the last thing to rule out would be black holes. Black holes can bend light from other objects, which causes an observable lensing effect, thus if it was black holes making up this dark matter, from lensing we would be able to make an estimate of the size of these black holes and potentially account for it.

So what does this leave? There are several theories as to what it might be, and the simplest of them all is that dark matter is merely "normal" matter that is not visible to us. This would be things like dark galaxies, planetary dust, and brown dwarfs. This is certainly a possibility and may account for what is currently missing. Unfortunately, right now there is not much that is known about dark matter, and due to its nature it appears to be something that will be difficult to peg down and define. The basis of science is to seek the truth, and naturally the more we learn the more questions it raises. This is something that may not be answered in our lifetimes or even our children's lifetimes, but eventually it will be answered, and raise more questions. □

# Binary Star Systems

BY ZHE QU, ELECTRICAL AND COMPUTER ENGINEERING, 2014

A binary star is a system consisting of two stars orbiting around their common center of mass. It seems like common sense that gravitational forces exist between subjects. Physics also teaches us that the amount of gravitational force is inversely proportional to the square distance between the subjects. In the case of a binary star system, the two stars are too close to each other, and the conflicting gravitational force between these stars has a significant influence on their orbits.

So, since the stars are so close, why don't they collide? Mathematically speaking, the gravitational force between the two stars provides the centripetal force for sustaining the circular motion of both stars. Thus, the two stars in the binary star system can keep a stable status. In our galaxy, 80% of the stars are binary stars. Usually, we define the brighter star of the binary star system as primary star, and the other is defined as the companion star. Even a star and a black hole can form a binary star system.

There are some researchers who believe that in our solar system, a companion star of the sun exists outside of Neptune's orbit. Two teams of astronomers, Daniel P. Whitmire and Albert A. Jackson IV, as well as Marc Davis, Piet Hut, and Richard A. Muller, independently published similar hypotheses to explain Raup and Sepkoski's extinction periodicity in the same issue of the journal Nature [1][2]. Since the orbit of Neptune is erratic, and possibly affected by a gravitational force outside that of the orbit, and Pluto is too small to provide such a large force, it is likely that an undiscovered star exists outside Neptune's orbit. These scientists believe that the companion might be a red dwarf or a brown dwarf. If this star existed, it would be between 50,000 and 100,000 astronomical units from our sun. So far no observations or evidence can support this hypothesis.

How binary star systems form is still a topic for astronomers. According to some hypotheses, the companion stars were once part of the primary star

and somehow escaped from the primary star in order to form the binary system. Other astronomers support the hypothesis that the companion stars are captured by primary stars as a result of complex movement of celestial objects.

Unfortunately, it is hard to have a stable planet orbit in a binary star system. In a singular star system, the gravitational force on the planet as a result of the sun is always vertical (proportional?) to its velocity. Thus, it offers the centripetal force necessary for the planet to sustain circular motion around the Sun. In a binary system, the gravitational forces of the two stars affect the planet, and so the total amount and direction of the velocity fluctuates between points in time. With the help of advanced mathematics methods such as calculus, as long as we know the current status of the planet in the binary system and other necessary parameters, it is not hard to predict the movement of the planet. With the unstable orbit, it is impossible to support life as we know it in these kinds of stars, because the temperature changes dramatically from time to time. The life of the planet itself is also a problem, because without proper initial conditions, it is very likely that the planet will eventually hit the Sun.

However, it is possible for a planet in the binary star system to have a stable orbit. The planet can have a stable orbit as long as it is far away enough from the two stars, so the gravitational force from two stars can be added together and treated as a whole. In this case, the two stars together are equal to one, and the planet acts as if it was rotating around one star. But in this case, the temperature is extremely low since it is very far away from the Sun. Without receiving enough energy, it is hard to support life on these planets. n

# Life on Europa

BY TUSHAR SWAMY, ELECTRICAL ENGINEERING/PHYSICS, 2015

Aliens have always captivated the human imagination, from UFO sightings to science fiction media like *War of the Worlds* or *Avatar*. Skeptics have always been sure to mention the distinct lack of physical evidence of life on other planets. However, recent discoveries and experiments have begun to bring real evidence to light. The current contender for extraterrestrial life lies on one of Jupiter's moons, Europa. Europa has long been noted for the large bodies of water hidden underneath its thick layers of ice. These water bodies were suspected to contain extraterrestrial life, but it was unproven until conclusive evidence came from the Galileo Millennium Mission. The Galileo probe's original mission was to fly to Jupiter, but this mission was extended to look at its moons (namely Io, Ganymede, and Europa). Close flyby images of Europa's surface were enough to confirm scientists' suspicions. But water in itself is not enough for life; the extraterrestrial organisms would also need some sort of energy source.

Up until the 1970s, scientists thought that the Sun was required in some form to provide energy, whether it was through direct contact, like photosynthesis, or indirectly, such as the consumption of an organism which had experienced direct contact with the Sun. In the 1970s, scientists found deep-sea creatures that were able to process energy via chemosynthesis. They were able to use substances emitted from deep sea hydrothermal vents, such as hydrogen and sulfide compounds, as an energy source in lieu of the Sun. This has led many scientists to speculate that Europa could harbor microbial life via similar deep sea vents. However, many challenges still stand in the way of producing physical evidence of life. Probes like the Galileo have flown by Europa, but still have not landed on Europa itself. In addition, any probe would have to withstand the massive levels of radiation emitted by Jupiter. The Galileo probe intentionally left radiation-intensive portions of the mission to the end, in case the probe was destroyed by the radiation. Despite all of NASA's planning, the radiation still brought down Galileo for a short time before they were able to bring the probe back online.

Even if the radiation could be mastered, any probe sent to Europa would still have to drill through the large sheets of ice covering Europa's water bodies. The ice is thought to be on the order of 10 miles thick. It would then have to be able to dive through the water itself to retrieve samples. Coupled with the recent budget cuts in programs like NASA, missions to Europa are still a while away. The closest option is the Juno spacecraft launched

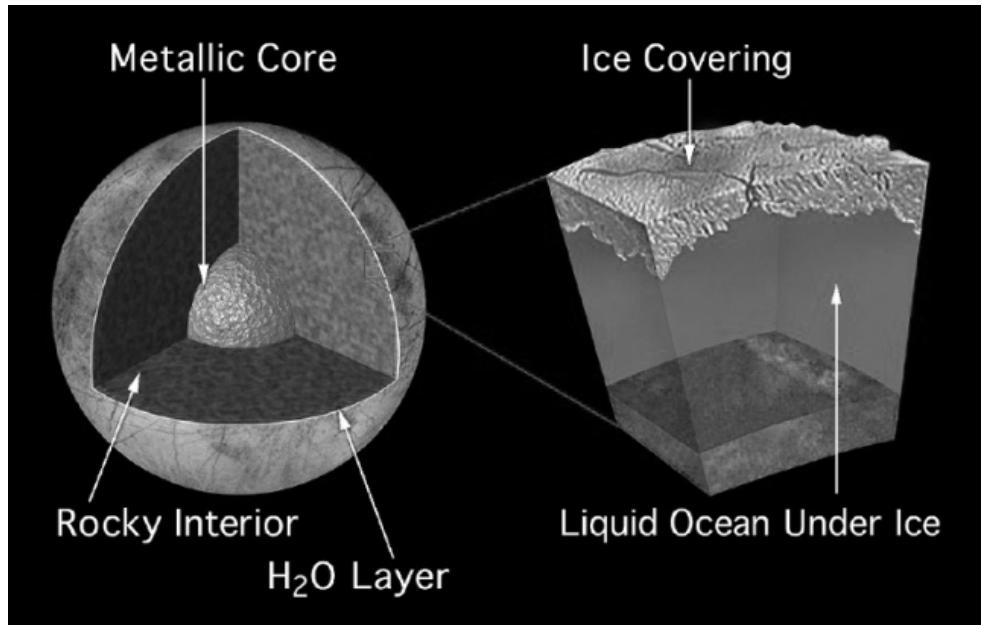


Photo courtesy of phys.org

in 2011, although Juno was specifically designed for Jupiter, not its moons. There is also the JUICE (Jupiter Icy Moon Explorer) spacecraft proposed by the European Space Agency, which hopes to be the first to land on Europa and take surface samples (no deep sea diving), though this is still in development. At its earliest, it will launch in 2022. Even though the prospect of a mission to Europa's depths in the immediate future seems grim, there are still many experiments and projects happening on Earth which could provide insight to Europa's conditions. One of the most exciting terrestrial developments was a recent expedition to Antarctica's Lake Vostok.

Lake Vostok is a large subsurface lake, covered by a huge, 25 million year old sheet of ice. The ice is so thick that the lake has essentially been isolated from the outside world since the Miocene Epoch. This provides a unique environment since it effectively simulates the conditions on Europa. Certain bacteria specimens were found in the ice on the surface, and plans are underway for a robot to enter the lake and collect specimens to assess the living conditions in the lake itself. Finding life forms here would definitely go a long way to proving Europa's potential for life. Other experiments currently underway involve observing the effect of radiation on Europa's life and environment. Scientists at the NASA Jet Propulsion Lab of the California Institute of Technology have been developing experiments where radiation

bombards ice and organic molecules. The idea behind the experiment is that one can see how far the radiation penetrates the ice. This is important because if the radiation penetrates too deep, it could harm whatever organic life might be living under the ice itself. The group conducted experiments by firing electrons at ice via an electron gun. They placed detector molecules behind the ice to gauge the penetration of the electrons. They then repeated the experiment with varied ice thicknesses. In the future, they hope to get the funding to perform the experiment at higher energy levels. In addition, the group is working on modeling the changes in radiation levels due to Europa's orbit around Jupiter. The hope is that a well designed model could give a probe a fighting chance at making it to the surface of Jupiter. Overall, the evidence for life on Europa is getting stronger with each new discovery. Europa remains one of, if not the best, contenders for extraterrestrial life in our solar system. The final step is to send a probe to acquire the long-awaited tangible evidence, though many challenges still stand in the way. n

# The Fiery Catastrophe that Resulted in the Moon

BY SHANNON JONES, MARINE BIOLOGY, 2016

The moon is a constant in the night sky. It's kind of hard to not notice it. That's probably why people have been coming up with explanations for how it got there for almost all of human history. These hypotheses have included gods, as in Roman and Greek times, but for most of the 19th and 20th centuries, three hypotheses were dominant – the capture theory, fission hypothesis, and co-accretion.

Capture theory basically states that the moon was a lonely wandering space object looking for a gravitational force. It got too close to the earth, and was pulled into orbit. This seemed unlikely to scientists, because it was unknown what could have pushed the moon close enough to the earth for capture while avoiding all of the other planets in our solar system.

The fission hypothesis seemed slightly more credible. This theory rests on the idea that the earth and the moon are dependent for each other for orbits; the moon is very slowly getting farther away from earth. Using this, it was thought that if the moon is getting farther away and the earth's rotation is decreasing, at some point the earth and the moon must have been one body. The earth was rotating quickly and was unstable, and it became an asymmetrical oblong shape. Then a part separated, forming its own rotation and allowing the unstable earth to stabilize and slow in its rotation. The proto-earth would then develop separately from the proto-moon, as the moon slowly moved further and further away. This is flawed in two ways: physics has proved that the proto-earth would have required an external catalyst to make it unstable, and a combined proto-earth/moon body would be too large to experience fission so unequally.

The last theory pre-moon landing theory was co-accretion, or dual formation. This was the oldest theory, and the simplest – as matter condensed into the proto-earth, it also condensed into the proto-moon. This was proved inaccurate when we landed on the moon and discovered that it's composition was slightly different than that of the earth.

Since the moon landing, we've learned a lot more about the composition of the moon. The current theory is that a giant space object crashed into the proto-earth and made a big mess that resolved itself into the moon and the current earth. This was shown in the Apollo program's samples. The samples contained levels of iron, nickel and cobalt that were not in the normal range for meteorites, and a ratio of tungsten isotope 182 to 184 that is the same as the tungsten in the earth's mantle. The moon was also found to have a core that had the same amount of oxidation as the earth, beginning 4.5 billion years ago.

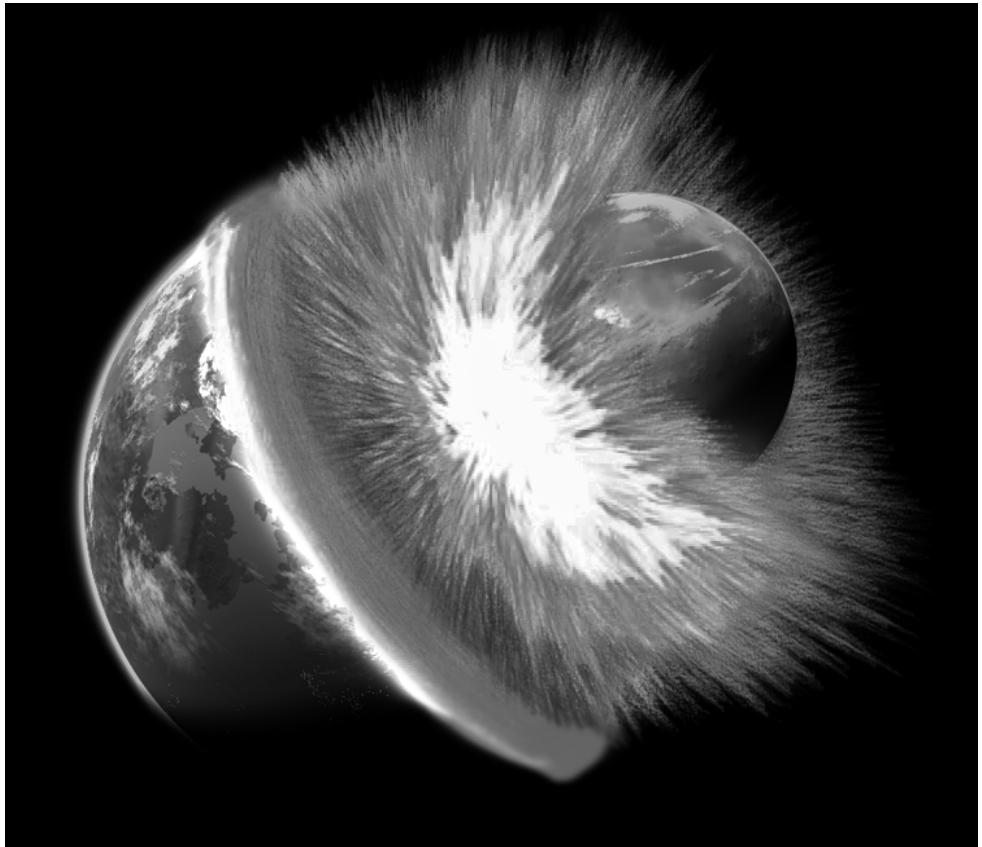


Photo courtesy of community.emc.com.

The current theory to explain these findings is called "the Giant Impact" and it is hypothesized to have occurred when a proto-planet about the size of Mars today crashed into the proto-earth. The material that was blown outward condensed slowly into the moon, with the rarer metals dissipating in space. This combination of pieces from the proto-earth's crust and an impacting planet body would explain the mix of elements found on our Moon.

Though there are still more theories out there about how the moon came to be, most of which involve alien life forms, scientists have agreed that the giant impact is by far the most likely. Unfortunately, until time travel is realized, we'll never know what happened. Still, most nights, we can look to the sky, and see the moon – the result of a world-changing collision, and a topic for debate. □

# Are Humans Causing the Sixth Mass Extinction?

BY CAT FERGUSON, BEHAVIORAL NEUROSCIENCE, 2013



**E**veryone remembers the dodo. It is a symbol of humanity's stumbling destruction, of the ignorant and accidental loss of an innocent. There is little doubt about how the dodos shuffled off their mortal coils: humans hunted them to extinction. Less is known about the cause of rising rates of extinction of other organisms around the world, but scientists can speculate.

There have been five major extinctions in the history of life on Earth. An extinction event is characterized by the loss of 75% or more species. Anyone who has seen the *Land Before Time* knows that the dinosaurs met their end about when one or more giant asteroids crashed into Earth, filling the atmosphere with ash and dust. This likely interrupted photosynthesis, resulting in massive disruption of food chains around the world. In addition, even after the ash dispersed, acid rain from sulfur dioxide, climate change from CO<sub>2</sub>, and other greenhouse gasses probably remained to exacerbate the deadly conditions. Massive increases in volcanic activity likely caused a similar one-two punch. The proposed root of other mass extinctions are also varied, but many of them mirror modern environmental changes.

Acid rain is the result of sulfur dioxide and nitrogen oxides being released into the atmosphere. Before humans, those emissions were mainly from volcanoes and lightning. However, since the Industrial Revolution, coal-burning electrical plants, factories, and cars have released massive volumes of sulfur dioxide, leading to stone statues with their faces melted off, uninhabitable lakes and streams, and contributions to deforestation.

Greenhouse gasses, too, have been linked to the destruction of habitats (and, therefore, the destructions of the species that rely on them). Carbon dioxide dissolves in the oceans, leading to ocean acidification, widely tied to the death of marine organisms, while atmospheric greenhouse gasses contribute to climate change and subsequent dramatic changes in weather patterns.

Evidence from past extinction events show that an individual catastrophe is unlikely to be the cause. Instead, there is probably a tipping point between many intersecting damages. Overfishing, overhunting, human-introduced invasive species, and pollution are also threatening biodiversity by creating stresses that no species have evolved to survive.

It is hard to give exact rates of extinction, past or present. Because fossilization requires a rare combination of parts that preserve well and perfect environmental conditions, the fossil record is heavily biased towards certain morphologies and locations. Soft tissue is almost never preserved, which makes distinguishing between species especially difficult.

That means the record of ancient organisms is likely laced with synonyms, or species that have been ascribed two separate taxonomies, as well as distinct species that have been mistakenly combined.

Discovering and defining living species has its own severe limitations. Though 1.3 million species have been classified, a recent study in PLoS Biology estimated that the real number is about 8.7 million eukaryotes (leaving out bacteria, which provide their own perplexities). This leaves the number of undiscovered species on land at about 86%. The percentage of unknown marine species is suggested to be an even more startling 91%. A good example of the challenges comparing historical and modern extinctions is bivalves, a class including clams and oysters. They are relatively good at fossilizing, allowing scientists to say with some certainty that approximately 49% of bivalve species went extinct during the Cretaceous-Paleogene event (more famous for wiping out the dinosaurs). However, only 1% of modern bivalves have been classified, allowing very little room for comparison.

Scientists are able to calculate a range of reasonable "normal" extinction rates, using a combination of fossil records and statistical modeling. This can then be compared to the estimated modern rate of extinction, based largely on plants and animals thought to be endangered or extinct. Though only about 1% of modern species have gone extinct, if current trends hold, 20%-50% of species could be lost in the near future. "If currently threatened species -- those officially classed as critically endangered, endangered and vulnerable -- actually went extinct, and that rate of extinction continued, the sixth mass extinction could arrive within as little as 3 to 22 centuries," says Anthony Barnosky, a paleontologist at UC Berkeley.

300 years may seem like a long way away, a hazy vision of jet packs and mind-uploads. But on a geological scale, it is not so much an eye blink as a single retinal cell firing. It is ten generations down the line from you. And it is very likely that the effects of species loss will become apparent, even to this generation.

Robert May, a zoology professor at Oxford University and previous chief scientific advisor to the UK government, has written, "We are astonishingly ignorant about how many species are alive on earth today, and even more ignorant about how many we can lose yet still maintain ecosystem services that humanity ultimately depends upon...biodiversity is much more than beauty and wonder, important though that is. It also underpins ecosystem services that--although not counted in conventional GDP--humanity is dependent upon." n

Photo courtesy of [theswissrock.wordpress.com](http://theswissrock.wordpress.com).

# The Ethics of Mass Extinction

BY SUMAYAH RAHMAN, BIOLOGY, 2015



Luristan Newt.  
Photo courtesy of *The Featured Creature*.



Saola. Photo courtesy of *Its Nature*.



Saola. Photo courtesy of *World Wildlife Fund*.

**T**he pygmy three-toed sloth. The spoon-billed sandpiper. The Baishan fir. These are just a few of the 100 species listed on a recently released report by the Zoological Society of London (ZSL) and the International Union for Conservation of Nature (IUCN) called "Priceless or Worthless? The world's most threatened species." The report is a breathtaking display that showcases these threatened species using color photographs and captivating descriptions. On each page, the ZSL and the IUCN offer a solution, explaining strategies and techniques that could save each species. This report is meant to inspire people to put forth conservation efforts in order to reverse the declining trends.

The species listed have a few things in common: They're close to extinction, and humans are the likely cause for their unfortunate situation. However, another notable shared characteristic among these animals, plants, and fungi is that they do not provide any obvious benefit to humans. Jonathan Baillie, Conservation Programmes Director of the ZSL, stated, "If the 100 species on this list were to disappear tomorrow there would be little impact on the global economy, jobs or security. This is in fact the case for millions of species on the planet, where their value to humanity is unknown or tangential at best."

There have been five mass extinctions, events in which there was a sharp decrease in the diversity of life on Earth. If current trends continue, the world may be heading toward its sixth. Currently, many organizations tout the value of saving plants and animals that serve some purpose for humans, but the "worthless" species are left unprotected. The scientists behind the ZSL/IUCN report and

several other environmentalists believe that this is the wrong approach. But the question remains as to why precious time, energy, and resources should be devoted to saving something that has no apparent benefits.

The saola, also known as the Asian unicorn, found only along the Annamite Mountains of Laos and Vietnam, is one of the rarest mammals on earth. Related to cows and goats but looking like neither, it is also one of the most distinctive. Although there have been a few civilian sightings, saolas have never once been seen in the wild by a scientist. And due to hunting, infrastructure development and extractive industries, it is possible that they never will be. Do the saola and the many other species close to extinction have an intrinsic right to exist?

Strict utilitarians would say no. Extinction is part of the earth's natural cycle, and species come and go. Humans do not have an obligation to alter our way of life to protect flora and fauna that have no purpose to us.

However, looking at the opposite side of the coin, we could say that living organisms have the kind of intricacy and beauty that we could never replicate by artificial means.

The Luristan newt lives in fast-flowing streams on the southern Zagros Mountains, in Lorestan, Iran, and can be recognized by its stunning black, white, and orange pattern that serves as a warning for its toxic secretions. The male newts perform an elaborate courtship dance before they mate, undulating their tail in front of the female's face. After this dance, the male drops a sperm packet, which the female then collects. Interestingly, the two newts do not touch one another throughout this entire ritual.

The dance of the Luristan newt is the result of millions of years of evolution. It is part of the newt's pathway to success that helped it to survive and reproduce for so long. There are less than 1000 of these newts left, and together they represent a tiny twig on the proverbial tree of life. But if habitat destruction and extreme droughts continue, this tiny twig will undoubtedly break off.

Although working to protect this newt and other threatened species might seem like it has purely aesthetic effects, this may not actually be the case. A recent study conducted by Matthew Bracken, professor of Marine Biology at Northeastern University, showed that rare species are vital to ecosystems. He performed an experiment in which he removed a combination of sessile (immobile) species that comprised less than 10 percent of sessile biomass (i.e. the rare species). This caused a 40-50 percent decline in consumer biomass, presumably because the rare species were integral in providing a habitat or food for the consumers. Clearly, the effects of having a high level of biodiversity are more far-reaching than previously imagined.

The greater bamboo lemur. The red-finned blue-eye. Priceless or worthless? It's up to us to decide. n



# Open Access Journals and its Abiding Effect on the Scientific Community

BY CAYMAN SUMMERSVILLE, BIOLOGY MAJOR, 2017

No former generation has been exposed to the advanced technology we experience today. Before Google, answers came from books and the accomplished, not from a box connected to the Internet. Research was conducted through scientific journals and prestigious publications that could only be acquired through expansive libraries or personal collections. As technology continues to advance, research simultaneously moves forward as well. It has become evident that the publication of printed scientific journals no longer makes sense fiscally or scientifically. The public should not have to pay exorbitant prices or wait long periods of time until publication to see the findings of an incredible discovery that has occurred today. It is for this reason that many researchers are moving towards publishing their work in open access journals. According to The Right to Research Coalition, open access literature is "free, immediate, online access to high-quality, peer-reviewed scholarly research coupled with the unrestricted rights to use it in new and innovative ways." Of the 8,210 open-access journals available today, one currently belongs to Northeastern University: *Annals of Environmental Science (AES)*, founded by two members of our very own university.

To collect as many details as possible about open access literature and AES, I conducted three separate interviews regarding different components of the journal. During an interview with Dr. Elham Ghabbour, the impressive Senior Editor of AES, I learned more about the work behind launching, writing, and running an open access journal. She assured me that the journal is a unit, and that it would be nothing without the support from everyone involved. Like the emergent properties of cells, all the people involved have to work together to keep a scientific journal running.

In 1993, Elham Ghabbour brought humic acids research to Northeastern. Today, she is Principal Research Scientist in the Department of Chemistry and Chemical Biology and Leader of the Humic Acids Research Group headed by Professor Geoffrey Davies. In addition, she devotes time to Co-Chairing the 16th Humic Science and Technology Conference to be held at Northeastern, working as a Senior Specialist in Environmental Health and Safety, and editing the open-access journal AES.

## The Foundations of AES

Along with the two other founders, Drs. Elham Ghabbour and Geoffrey Davies, Dr. Robert Wershaw introduced open access at an

international conference on Humic Substances held at Northeastern University in 2002. The proposal to generate an open access environmental journal was inspired by a lecture he gave, highlighting the escape from outrageous costs associated with print journals and the creation of more space in libraries through online publication. Despite the fact that the medical field was already publishing online, many of the founders' peers were unsure if open access journals reflected the same quality as print scientific journals. Many scientists were interested in opening access to their research, but were discouraged by a lack of comprehension on the specifics of open access literature. According to Hillary Corbett, the Scholarly Communications Librarian of NU, "A common misunderstanding is that open access means you are just paying somebody to put your article on the web and there's no peer review, there's no quality insurance and that's absolutely not true." In general, communicating personal research is part of "scholarly communication" and helps insure the rigor of the research. Open access is carrying out this goal, while simultaneously meeting the substantial goals of any scientific journal.

It is well known that science journals are high priced, which is why advocates of open access appreciate the economics of online publication. Before, if a library or an individual wanted to obtain a scientific journal or simply a paper from a journal, they were required to purchase the paper or entire journal from the publisher. Not only are the journals incredibly expensive, a commercial journal cannot be scanned without breaking the copyright law. Students, researchers, and even professors have been denied access to important information because they or their institution can't afford the \$5,000, \$10,000, or even \$20,000 per publication annual subscription prices. Around 2002, universities and libraries were frustrated by budget cuts that led to the inability to continue subscriptions to a number of journals. Funds needed for published research typically come from grants or publishers. Often, publication companies are predominantly focused on the profit margin, charging every party involved: the university, authors, and readers. Not only does this hinder the education of students, it also delays the transmission of new material. This frustrating situation prompted the foundation of open-access journals such as AES. Usually, the publisher owns the right to an author's published work; however, with open access the author retains the right to their own work. Additionally, people are able to build on it without having to pay to a publisher. As

The screenshot shows the homepage of the Annals of Environmental Science (AES) journal. At the top, there's a navigation bar with links for Safari, File, Edit, View, History, Bookmarks, Window, Help, and a search bar. Below the navigation is the URL http://www.aes.neu.edu/. The main header features the Northeastern University logo and the journal title "ANNALS OF Environmental Science". To the right of the title is a sidebar with links for TABLE OF CONTENTS, FOR AUTHORS, FOR REVIEWERS, and ABOUT THE JOURNAL. Below the sidebar, there are sections for CONFERENCES & NEWS, featuring the "Sixteenth Humic Science & Technology Conference" at Northeastern University, Boston, March 20 - March 22, 2013. There are also abstracts for "Sources of Fecal Indicator Bacteria to Groundwater, Malibu Lagoon and the Near-Shore Ocean, Malibu, California, USA" by JA Izicki et al., and "Onsite wastewater treatment...possible source of fecal indicator bacteria...Malibu Lagoon...Escherichia coli...as high as 130,000 MPN/100 mL...50% of Bacteroidales and Fimicutes OTUs present in the near-shore ocean were also present in gull feces." by P Vidon, et al. At the bottom of the page, there's a footer for EdTech developed by the Educational Technology Center, with a copyright notice from 2007-2012 Northeastern University.

modern culture rapidly evolved and recognized the significance of technology in our future, scientists began to appreciate the unique benefits of open access in improving communication.

The incredible goals of Dr. Ghabbour and her colleagues were achieved when the first volume of AES was published in March 2007, containing twelve contributions. A new volume is published each year, with the most recent volume, Volume 6 (2012), containing research on humic acids by the founders themselves. Dr. Ghabbour emphasized that the journal is based on team effort. They have an International Editorial Board with members from France, Scotland, Switzerland, and the USA. AES receives submissions from all over the world including Australia, Japan, and India.

The only cost of open-access journals is the time of the editors, reviewers and the authors; no one is paid to publish the work because there are simply no costs associated with the publication. Northeastern's strong research program is what distinguishes it as a leading university. Open-access journals encourage the younger, more tech-savvy population to read scientific journals and utilize the research in their own studies. People from all over the world are now able to have free access to journals. Dr. Ghabbour illustrates the benefits of open-access journals by giving the example the monograph 'Systematic Approaches to Comprehensive Analyses of Natural Organic Matter' by Jerry A. Leenheer, which is used as a text at several schools across the country.

Hillary Corbett supported this statement, explaining, "Something that appeals to a lot of people is being able to communicate scientific information with researchers in developing countries where everyone can afford to have a subscription through the university...That's one of the reasons why open

access to that research is important." Corbett also pointed out that open access provides educational opportunities for students who graduate from university but plan to learn more about a particular field.

### The Mechanics Behind AES

The open access journal was started at Northeastern University because of IRis, a permanent place to store the intellectual property of NU digitally. Hillary Corbett explained that IRis is a location where research output is collected. It is useful for the conservation of records, promotion of research, and the pursuit of NU publications. Through IRis, work can be made permanently available, insuring that information produced by the University is kept publicly accessible at all times. There are over 5000 items on the IRis server, including AES. AES was welcomed by Northeastern University because of the modern movement of storing content from research onto servers, like IRis, to conserve property.

As part of her position, Hillary provides people with an overview of the important meaning of open access in research. According to The Right to Research Coalition, open access has the potential to "speed up research, advance science, and open new avenues for discovery." Providing students access to high-quality research can enhance their education and allow researchers to better share their findings, allowing more discoveries to be made sooner. This revolutionizes information-sharing, and is made possible by hardworking people like Dr. Ghabbour and her Editorial Board.

AES is considered a very selective journal, with an acceptance rate of only thirty percent. Despite the unique nature of the open-access journal, the process of getting one's work published is similar

to the traditional print journal process. After a manuscript is submitted, the editors must evaluate the piece's significance, and reject any unqualified work, uninformative data, and already published findings. Once the paper has been deemed a successful candidate for AES, each paper is sent to four or five researchers for a peer-review process. After the reviewers' comments are returned, the fate of the paper is determined. Finally, if accepted, one of the AES Editors authorizes the final publishing.

### One AES Contributing Author's Experience

Forde Hellweger, a well-known environmental science professor at Northeastern, published a paper in Volume 5 of AES. The paper focused on antibiotic-resistant bacteria in the environment. In an interview with Dr. Hellweger, he praised online journals like AES for their expeditious publication time and for being "widely accessible by the research community." As Hellweger pointed out, the majority of this generation accesses journals and research online, rather than through printed publications. Having been published in open-access journals prior to AES, Hellweger highlighted the benefit of this immediate access to knowledge for the scientific community and public.

When I spoke with Dr Ghabbour, her passion for research and academia was evident. She discussed her interest in a recent paper published in AES that was conducted by the US Geological Survey. The research, "Sources of Fecal Indicator Bacteria to Groundwater," investigated sources of pollution in Malibu Lagoon, California. The paper's layout clearly portrayed the hard work of the editors. There were beautiful colored illustrations and diagrams of the area studied and sampled, as well as the components of a standard article, such as an abstract and a methods section. The lasting impression was that the editors are committed to accurately presenting the research, in a desirable and scientific way, to all potential readers.

When Dr Ghabbour first came to Northeastern, in the middle of her thesis, she spent hours in the library researching. Now, her trips to the library are rare, as she explains, "The library is in my computer!" Still, the library has to pay many subscriptions to journals—unless they are open-access. Even if they are digitizing scientific journals to make more room, they are still required to pay the publisher as if buying printed versions of the journal. Currently, many in the academic field have a hard time getting their hands on papers they need to read. However, open access has the ability to provide knowledge to an enormous number of people. Our generation has access to an abundance of knowledge, and it is clear that the progression of its availability will continue only if journals like AES exist.

NU Science is grateful for the contributions of Geoffrey Davies to this article. n

# Mosquitoes bite back: The reemergence of West Nile and related diseases

BY KRISTEN TATSUNO, ENVIRONMENTAL STUDIES, 2016

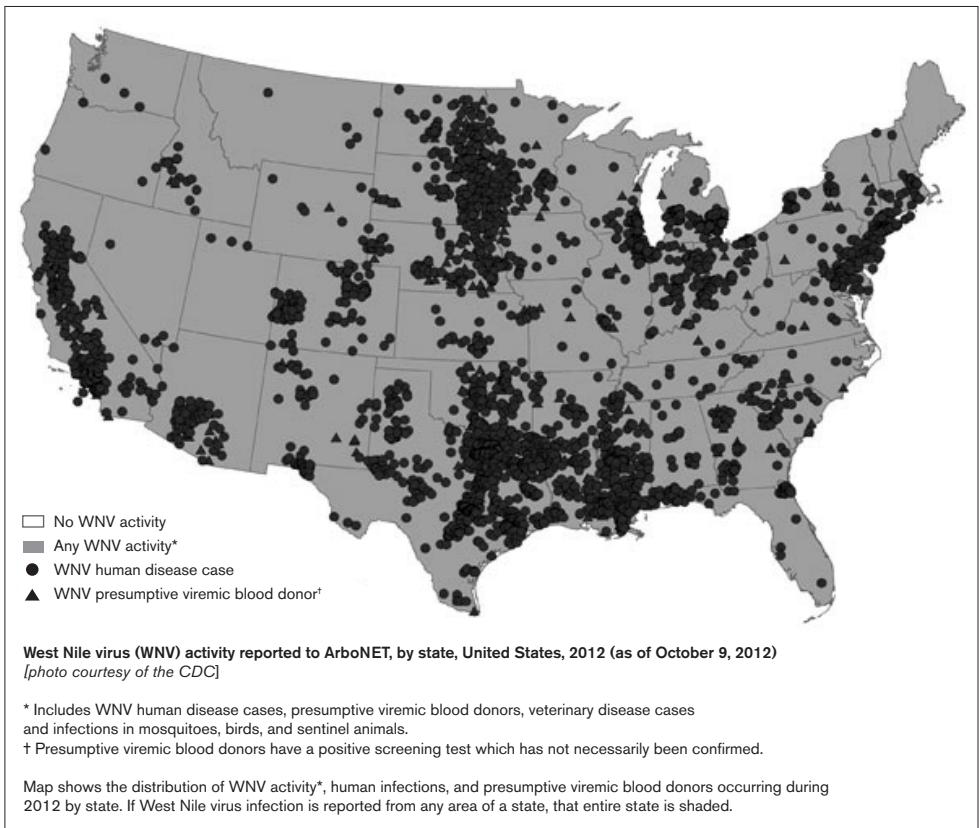
For most people, a mosquito bite simply means a week or two of scratching and slathering on anti-itch cream. Annoying? Yes. Life-threatening? No. But for over 4,200 Americans, mosquito season meant a few weeks of fever, stiffness, rashes and headaches. In the worst 168 cases, it meant death. These numbers are as of October 2012; with continuing reports of new cases from the continental U.S., this year could surpass 2003 as the worst outbreak in U.S. history, and scientists are scrambling to find a cause.

West Nile was first diagnosed in Uganda in 1937. From there it spread into Europe, the Middle East, west and central Asia, and Oceania beginning in the 1960s. It finally surfaced in North America in 1999. The virus spreads quickly along the migration paths of infected birds, which mosquitoes feed on. After a few days in the mosquito's body, the virus moves to the mosquito's salivary glands, thereby infecting any host it bites.

Humans can only get West Nile through bites from infected mosquitoes and, in extremely rare cases, from transplanted organs, blood transfusions, or a mother's transplacental transmission or breastfeeding of her child. A vast majority of those infected see no symptoms, but in others, the virus can manifest as West Nile Fever or neuroinvasive disease. While both West Nile Fever and its advanced neuroinvasive stages (encephalitis or meningitis) cause an equal number of deaths, the latter is considered more dangerous, because it can leave survivors paralyzed or in a coma.

Massachusetts alone has seen its number of West Nile cases skyrocket from six cases in 2011 to 22 this year through October, including a few cases in the Boston area. Texas, the state hit hardest, has seen 40 percent of all U.S. cases. Another six states, California, Louisiana, Michigan, Mississippi, Oklahoma, and South Dakota, have seen the rest of over two-thirds of all cases.

Unfortunately, West Nile is not the only disease that mosquitoes can transmit. Though the U.S. is sheltered from the worst diseases through strong public health programs and funding for disease prevention, the country is still home to mosquitoes known to have carried the deadly viruses. Encephalitides are the most common serious viruses found in the United States. Mosquitoes in the U.S. have been found carrying Eastern Equine, Western Equine, La Crosse, and St. Louis encephalitis, all of which cause symptoms such as headache, high fever, chills and vomiting. If allowed to progress, the viruses can cause swelling in the brain, leading to disorientation, seizures, coma, and even death. There is a 33 percent mortality rate; survivors are often left with permanent brain damage. Massachusetts saw



its number of Equine Encephalitis cases rise from two in 2011 to six in 2012, with one fatality.

Scientists have been unable to pinpoint the cause of the spike in cases, but climate change is looking to be a likely culprit. Mosquitoes need standing water and warm temperatures to breed and mature quickly. And in the wake of heavy winter and spring flooding followed by the hottest summer on record, mosquitoes are enjoying some of the best breeding conditions in years. In addition, as a seasonal epidemic, the threat of West Nile and other mosquito-borne viruses will not be officially over until the first frost hits. Climate change in the Northeast could push back the first frost and raise winter temperatures, creating an extended period for mosquitoes to breed and travel.

The CDC is on vigilant watch for arboviruses not seen in the U.S. previously. If the climates continue to change, especially in the warm and wet American south, areas that were uninhabitable for disease-carrying could become Ground Zero for new epidemics.

Yet the CDC and epidemiologists are quick to point out the many factors that could contribute to

this arbovirus resurgence. They point to easier travel between countries, import and export of animals, the natural migration patterns of birds and genetic mutations as factors in the spread and subsequent larger outbreaks of disease. But they cannot rule out that the potential for drastic climate changes in some locations could put countries at risk for the emergence of new diseases.

For now, with vaccines for arboviruses still in the works and the uncertainty of the first frost, people are left relying on the same precautionary measures that have been in place for over a decade. The CDC calls them the four D's: Dusk/Dawn, DEET, Dress and Drainage. The CDC advises people to avoid spending time outdoors at dusk and dawn, which are prime mosquito feeding times; to use repellent that contains DEET; to dress in long sleeves and pants; and to drain all bodies of standing water. n

# In Support of Primary Prevention of HIV/AIDS

BY HEESU KIM, PHARMACY, 2018

**B**reathing new life into a decades-old campaign against HIV/AIDS, science has made fresh progress in the up-and-coming field of primary prevention research.

Acquired Immunodeficiency Syndrome (AIDS), debilitates the immune system through swift division of the retrovirus HIV, exposing individuals to opportunistic infections that seize upon the body's weakened defenses. Individuals affected with AIDS suffer from a myriad of symptoms, including depleted CD4+ T cell count and increased susceptibility to several key cancers and diseases. The disease is primarily transmitted through sexual intercourse, blood-borne transfusions, pregnancy, the birthing process, and breast-feeding.

HIV, which takes the forms of HIV-1 and the less common HIV-2, typically comprises a latent and asymptomatic incubation period that hides the infection until it has progressed into the advanced stages preceding AIDS. According to avert.org, HIV/AIDS affected an estimated global figure of 34 million people by the end of 2010.

The universal HIV/AIDS epidemic has incited a slew of research studies aiming to treat and ultimately cure the condition. Significant breakthroughs have been reached in past years, including longer life expectancies for patients undergoing treatment drug therapies. Additionally, several drugs can be administered in tandem to increase an individual's chance of recovery. In the wake of the many positive developments in the treatment of patients post-diagnosis, today a new upstream strategy of treatment is on the rise: preventative measures which seek to stop infection from occurring in the first place.

In August 2011, scientists released the astonishing results of a research study that called attention to the potential for prevention of HIV-1 transmission. The study, which principally observed 1,763 heterosexual couples, concluded that the use of antiretroviral drugs (ARVs) in heterosexual HIV-positive individuals decreased their likelihood of transmitting HIV-1 to their partners by 96%. Published in the New England Journal of Medicine, the discovery remains a major victory in support of the primary prevention of HIV/AIDS. The study has been selected by the publication Science as the number one scientific breakthrough of 2011.

Continuing the foray into early prevention of HIV infection, advances in pre-exposure prophylaxis (PrEP) have newly risen to the forefront of the HIV/AIDS treatment enigma. PrEP suggests that the application of ARVs to HIV-negative individuals can potentially reduce their risks of infection. The approach has engendered a debate weighing the



possible benefits and risks of its practice. A pressing concern of PrEP addresses the chance of individuals developing a dangerous drug-resistant strain to the ARVs commonly used in AIDS treatment. Inconsistent consumption of ARVs due to negligence on the part of the patient is also a valid concern.

The debate on PrEP has extended to the pharmaceutical company Gilead Science and their medication Truvada, an ARV approved by the FDA in July 2012 for consumption by healthy individuals at high risk of HIV infection. Individuals considered at risk include those whose partners have tested HIV-positive. Truvada, which is already used to treat HIV-positive patients, functions by impeding the retrovirus from multiplying in the body. In its PrEP manifestation, Truvada is taken as a means of primary prevention that reduces HIV-negative individuals' chances of acquiring the retrovirus.

Critics of this proposed application of Truvada have suggested that potentially increased risks of kidney damage dwarf the uncertain benefits of drug therapy. Further concerns have been voiced that individuals taking Truvada who are unaware of their HIV positive status could develop a drug resistant strain of AIDS. To address these issues, other clinical trials began in part to compare the potential side effects of Truvada, including Pfizer's Selzentry drug. A promising ARV that inhibits an HIV pathway, Selzentry has displayed fewer cases of developed resistance than the typical HIV/AIDS medication.

To assist scientists in determining the success rates of their experimental studies, a new test announced in August 2012 introduced an innovative method of testing HIV incidence. Called the Limiting Antigen Avidity Enzyme Immunoassay, the test was developed by the U.S. Centers for Disease Control and Prevention to measure the number of new cases of HIV in a population. Capable of measuring whether an individual was infected with HIV within the past 141 days, the immunoassay costs millions less than the existing method of testing. The test stands to assist scientists in economically observing which treatment methods more successfully decrease HIV incidence rate. The immunoassay is therefore a deeply valuable asset to scientists seeking to understand the efficacy of their treatment methods on HIV incidence.

The advances in early detection and primary prevention research come as increasingly urgent gains in the mission to cure AIDS and eradicate HIV. As the medical community begins to meet the challenges posed by an aging HIV-positive population, ever-climbing HIV prevalence figures will necessitate emphases on both prevention and treatment. This much is clear: ventures into primary prevention research stand to shift the tide in the fight against HIV/AIDS. Through continued openness toward reevaluating and refining HIV/AIDS treatments, a conceivable end is in sight. n

# NUSci Explains

## ...Antivenin

BY ASHLEY ALLERHEILIGEN, CHEMICAL ENGINEERING, 2017

**A** hiss, a flash of fangs, sudden excruciating pain -- you've just been bitten by a venomous snake. However, if you've been bitten in the United States, that bite only has a 0.2% chance of proving to be lethal, making a snakebite significantly safer than several of my family vacations. The widespread use of antivenin (more casually called antivenom) plays a huge role in keeping this fatality rate so low. The administration of antivenin can save a life in only a few minutes, but the journey from venom to antivenin spans several locations and many months.

Antivenin production begins with venom collection. Live snakes undergo a process called 'milking.' A glass vial with a rubber membrane stretched over the opening is prepared. A professional snake handler extracts the snake from its habitat, holding the snake behind the head. The handler then holds the snake's head over the vial. The snake strikes out at the perceived threat, injecting venom through the membrane and into the vial below. The milking process is harmless to the snake, but incredibly dangerous to the handler. The inherent risk leaves only a few specialized facilities and individuals responsible for supplying not only a great volume, but also variety of venom. Not only must venom be collected for each species, but for species that show a lot of regional variation, different venoms must be collected for each type.

Once the venom is collected, it's shipped off to the next stage of production. At this state, antivenin production takes advantage of certain animals' natural ability to produce antibodies against venom. The animal of choice is the horse, as it is easy to breed and handle. Each animal is then inoculated, that is, the venom is diluted and then injected into the animal. Just like with a flu shot or a chicken pox vaccine, the 'active ingredient', in this case the venom, is altered slightly so that it triggers antibody production without causing symptoms.

Once the animal is inoculated, a blood sample is taken to ensure that each animal has the right number and type of antibodies. Then, blood is drawn from the animal. From there, the antibodies must be extracted from the blood, a process that involves some pretty awesome science.

Remember that blood is a heterogeneous mixture; it has lots of ingredients of different sizes and shapes, from molecules of water to red blood cells. In order to separate these different ingredients, the blood is run through a centrifuge. A centrifuge spins the sample at high speed and the denser particles settle towards the outside of the rotation while the lighter particles settle towards the middle. So, the dense red blood cells end up at one end of the vial, while everything else (the plasma) ends up at the other end. The plasma can easily be extracted, leaving the red blood cells behind.

The plasma must be purified even further. Here's where the chemistry comes in. Substances are added to the plasma that react differently to antibody proteins in comparison to unwanted proteins. Some substances break the extraneous proteins down into simpler parts, while other substances cause the desired proteins to precipitate, or, to clump together and fall to the bottom of the vial. In this sophisticated process, filtration and centrifugation may be used several more times, as lipids are removed and the proteins are broken down into even simpler components. The end result is a solution with a high concentration of antibodies. Each batch of antivenin undergoes extensive safety and effectiveness testing before being finalized and packaged for distribution.

The effectiveness of antivenin is rather specific, for instance, cottonmouth antibodies do not work against cobra venom. The antivenin and the venom have to match. However, antivenin can be generalized by inoculating a single animal against several species or regional variations, resulting in something of a pre-made cocktail.

This specificity goes back to how antivenin works. Antibodies in general are a lot like hash tags on a tweet; they identify something as belonging to a certain category so that the rest of the immune system can destroy it. And while there may be One Ring to Rule Them All, there's not one antibody to tag them all. Each antibody only tags one kind of pathogen. The human body can make tags for chicken pox, measles, each strain of the flu, but not for snake venom. So what antivenin does is temporarily 'upgrade' the human immune system, letting it tag snake venom. Furthermore, like a muzzle on an angry dog, an antibody neutralizes the venom protein until the white blood cells come to break it down.

So, if you're ever bitten by a venomous snake and subsequently rescued by antivenin -- first of all, my sincere condolences for your incredible pain -- but secondly, remember to thank a herpetologist, a horse, and a centrifuge. n

# Interview with Assistant Professor Ben Webster

BY JOHN JAMIESON, CHEMICAL ENGINEERING, 2015



## BEN WEBSTER

Assistant Professor in Mathematics

PhD, University of California, Berkeley, 2007  
441 Lake Hall

In just his second year at Northeastern, Professor Webster has been awarded a CAREER grant by the NSF Division of Mathematical Sciences to promote his research in representation theory and knot homology. This award places emphasis on both research and education, and a portion of the funding supports a fellowship for a graduate student to conduct research. NU Science had the chance to talk to Professor Webster about his studies and his path to Northeastern.

### Why did you choose to study math?

It's hard to say why as a freshman in college I made that decision, but looking back, it's really suited me well. Math is so self-contained; you have control over your work without being at the mercy of some experimental apparatus or mice. I think math is about understanding truth, in a sense, its truth that is less coincidental than the rest of science.

### What is your research about?

This isn't the only thing I work on, but one part of it I tell people about is knots, because they're something that is concrete. If I give you two knots, how do you know if they're the same? There are an infinite number of ways to try to pull and twist to try to turn one into the other, so it's a very hard problem. But if you can somehow extract some piece of information, like a number or a vector space, from

these knots, based on the way they're twisted up, you can definitively say whether they're the same or not.

There are different ways to go about doing this, and I pull from different branches of mathematics with that aim. Sometimes you can get something simple like a number, but what interests me is when you can have more structure. Rather than just "3," you could get a set that has 3 things or a 3-dimensional vector space. This can carry more information, since you can have a map between sets or vector spaces, but not between numbers.

### What are some applications of research in this area?

Knots and braids (strands twisted around each other) show up in lots of really interesting places in mathematics and have connections to physics and quantum computing. When you have electrons trapped on an interface between two different crystals, there's actually interesting quantum mechanics in how they braid around each other; if you look at the probability that two of them switch places, you have to account for whether they switched clockwise or counter-clockwise. So, for many particles, you begin to see a "braid" or a pattern in how the paths they took, tangle.

This is one approach to quantum computing that people are working on. They set up the physical interface, and encode the program they want to

perform as the probability that the particles twist around each other in a specific way. It sounds very complex, but I've actually heard it described as the "second least crazy approach to quantum computing."

So that's one example. Generally in mathematics though you can't know what the application will be in advance. For instance, some very advanced mathematics is used to get your cell phone to switch between service towers in the best way possible when you're driving your car. But no one would have thought, "Gee, we should really develop the theory of pseudodifferential operators to help solve this problem."

### What tools do you use in your research? Are computer programs useful for the computations?

Mostly it's just pencil and paper. I use Google and Wolfram Alpha for some things. Extracting information from knots can be quite computational intensive, so I almost wish I could implement it as a computer program. But it's not something that off-the-shelf software is ready to do. It's not the sort of thing that people who wrote computer algebra packages thought people would ever need to do.

### What classes do you teach?

Right now I'm teaching the combined differential equations and linear algebra class for engineers. In the spring I taught a couple of graduate courses, and before that it was Calculus 1 for science and engineering.

### What do you like to do for fun?

One thing I really like is biking. I enjoy board games and cooking as well. I find it relaxing and fun. I've gotten to do a lot of the traveling associated with academia, and that's also been fun. There's always something you want to keep from every place you've been to.

### What would your advice be for undergrads thinking about doing research, in the math department or elsewhere?

Look into REUs (Research Experiences for Undergrads). These are summer research positions funded by the NSF. They exist for a wide range of studies, and they can really help you understand your interests better and whether or not you'll want to go to grad school and do research. ▶



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