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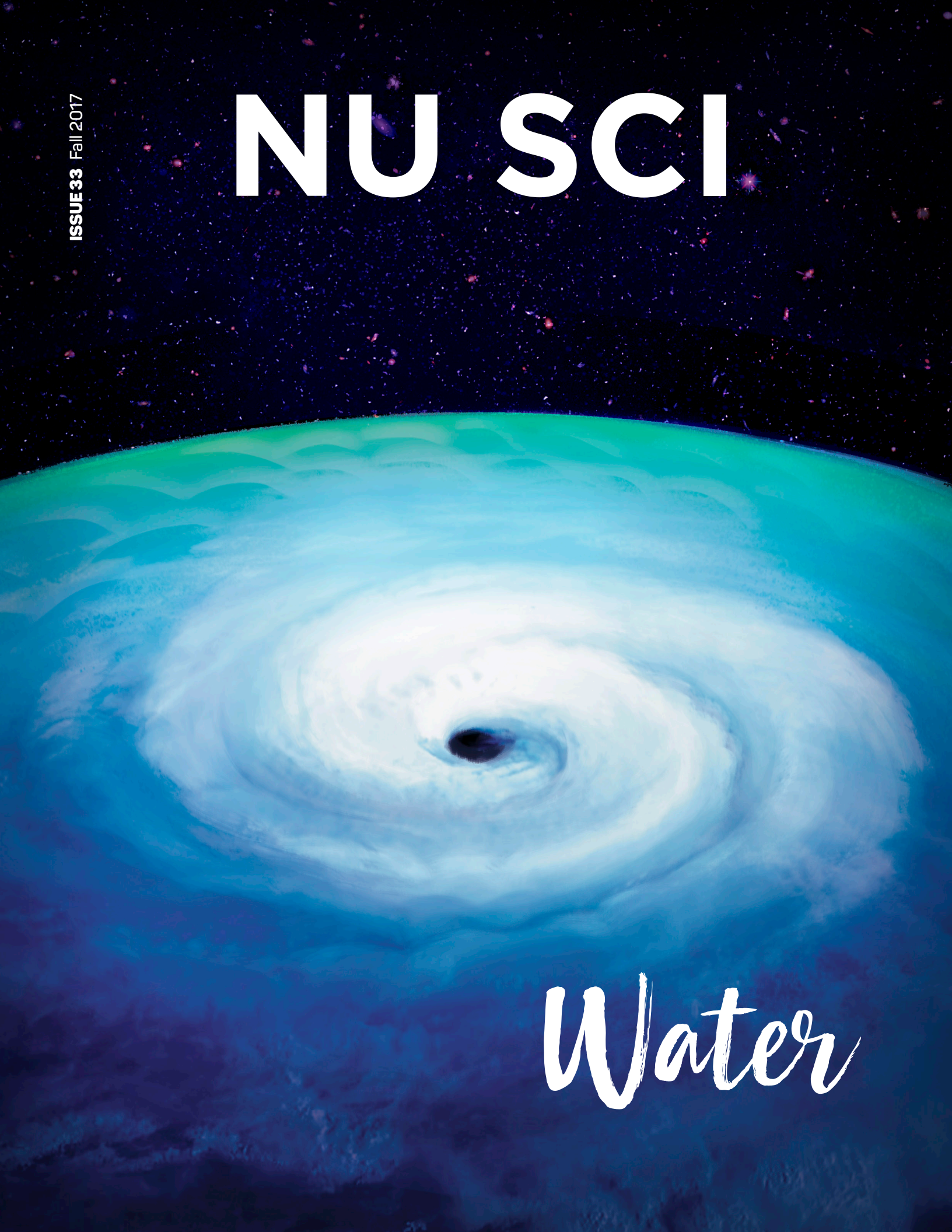
# NU SCI



## Water

# Staff



# Letter from the Editor

Da Vinci called it the driving force of all nature. It makes up about 60 percent of our bodies, covers over 70 percent of the Earth's surface, and according to U.S. Geological Survey, there are more than 332,000,000 cubic miles of it on Earth.

So it seems fitting for the theme of our 33rd issue of NU Sci to hone in on our world's most important resource. Water.

As the newest editor-in-chief of NU Sci, I am very excited to share this issue with you. I have been writing for the magazine since my freshman year at Northeastern. Now, as a fourth year, I have been a writer, editor, and secretary, gone from a Biochemistry to Biology major, and continued to explore my passions in science journalism. With every issue that we publish, I am impressed by the quality of writing we foster in our many new and experienced writers, the beautiful visuals created by our design team, and all the endless hard work behind the scenes. This year, we have added a new team of outreach ambassadors to connect our organization with the many science-affiliated clubs on campus. I am so proud to represent our magazine this year and hope to continue to help share our love for science with the community.

This November, we've also started a newsletter to share our articles, campus and club news, and more. Please subscribe at bit.ly/nusci!

Whether you love learning about every fish in the sea or are passionate about making a difference for our environment, this issue can quench your thirst for the science behind it. Read on to discover the creatures that lurk in the darkest depths of the ocean and the marine animals harmed by plastic pollution. You can learn about crazy weather patterns, high-tech water bottles, and newly proposed methods of underwater carbon dioxide storage.

We are also honored to feature the long-time research project of the faculty advisor of NU Sci, Dr. Geoff Davies. His work at Northeastern is featured in this issue alongside that of student researchers and a Madrid-based Fulbright Scholar.

So please dive into our 33rd issue. I'll see you on the other tide!

Sage Wesenberg
Editor-in-Chief

COVER DESIGN BY IRINA PYATAEVA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# The ocean needs you, not your trash

BY BRYNN VESSEY, BEHAVIORAL NEUROSCIENCE, 2019

DESIGN BY GATES SCHNEIDER, BEHAVIORAL NEUROSCIENCE, 2021

**Picture this -** it's a beautiful summer day, and the beach is the place to be. The ocean is sparkling with the sun reflecting off the water, and something catches your eye. But what is that something? More than likely, it's trash. It's approximated that 1.4 billion pounds of trash enters the ocean each year alone. Ocean pollution can take many forms, and come from a variety of sources, but the largest contribution to pollution in our oceans is due to land activities. Land objects like cars or trucks produce run off, as do septic tanks, ranches, and farms. Pollution in the ocean that comes from runoff is known as non-source point pollution. Most people are more familiar with point source pollution, from events like oil spills, as large sources of pollution are more heavily documented in popular media. It seems that ocean pollution is a more tangible problem when its effects are visible, like walking along the coastline and seeing the physical trash scattered in the water or on the sand, but the unseen effects of pollution are even more frightening.

> "It's estimated that 1.4 billion pounds of trash enters the ocean each year alone."

In 1974, a member of the Council of British Plastics Federation argued that plastic litter is a miniscule proportion of all litter, with no harmful effects to the environment except for its appearance. Over 40 years later, it's still difficult to draw attention to the impacts of pollution to the ocean.

So why should we? Why does pollution matter? Plastic pollution alone is estimated to affect at least 267 species worldwide, with 86 percent of sea turtle, 44 percent of seabird, and 43 percent of marine mammal species impacted. Plastic debris most commonly impacts marine life through ingestion of plastic, or entanglement within the plastic itself. Not only are these numbers astounding in the threat they pose to marine life with species endangerment and extinction levels on the rise, but there is also a noteworthy impact to humans. Over one third of waters where shellfish are grown for human consumption are negatively impacted by coastal pollution.

The impacts of pollution are becoming more and more widely acknowledged. Nutrient pollution can create algal blooms, dead zones in the ocean where algae's consumption of oxygen leaves little supply available to marine life, leaving spaces inhabitable. Marine debris left behind on beaches entangles and drowns marine life. It's clear to see that human activity has a significant impact on marine life, the oceanic ecosystem, and ultimately our own consumption of the resource that is the ocean; what is less obvious is what we can do to change our impact on the ocean. Tackling ocean pollution as a whole is a daunting task- but there are little things that we can do every day to help clean our oceans- and keep them that way.

Though small, microbeads found in many face washes are a contributing factor to oceanic pollution. Switching to a face wash or exfoliant that uses rice, bamboo, apricot seeds, or other biodegradable ingredients is a great option to limit pollution. Carrying a reusable water bottle has multifold benefits; the actual process of creating bottled water actually uses six times as much water per bottle than there is in the finished product. By utilizing a reusable water bottle, not only is water waste reduced, but there is less plastic waste to end up as pollution. Use of plastic bags should be avoided whenever possible. With more than one million plastic bags used every minute, banning their use could have a significant impact on our environment. Another way to limit pollution in the ocean is simple - whatever trash you bring to the ocean with you should also come home with you. The world's largest ecosystem's success depends on people taking small steps every day to protect it. The ocean is a beautiful resource- let's do our part to help keep it that way.



# Climate is changing our oceans, one ion at a time

BY DENNY TRUONG, CHEMICAL ENGINEERING, 2020

DESIGN BY JAMES GOULART, CHEMISTRY, 2021

**Most people acknowledge** that climate change is real, and even that the ocean has been acidified rapidly. Some would even know the cause of this acidification – the abrupt and gigantic rise of carbon dioxide ($CO_2$), but the hidden effects that a tiny drop in pH can have on the ocean and its residents is still largely overlooked.

The more carbon dioxide the ocean absorbs, the more hydronium ions ($H^+$) it produces, leading to a more acidic (lower pH) environment. As it currently stands, acidity of the ocean could increase by up to 150 percent by the end of the century, according to UNESCO. In parts of the ocean, pH can drop to as low as 7.9, compared to the current 8.1. It might seem like an insignificant change, but with pH on a logarithmic scale, a 0.2 change gives 1.6 times more $H^+$. Considering that the ocean is often a universal buffer, it would take so much more $H^+$ to decrease the pH even slightly. This increase in $H^+$ represents a massive change in oceanic conditions with catastrophic result, especially for the thousands of organisms like reefs that depend on the stable acidity of the water to survive.

Many sources have warned the world about the concerning decline of coral reef. According to NASA, as much as 27 percent of monitored reef formations have been lost. While some of this loss can be fairly attributed to direct human activities like dynamite fishing, ocean acidity plays a large part in this worrisome trend. Coral reefs, as well as the shells of many other shelled creatures, are made of calcium carbonate ($CaCO_3$). Extra hydronium ions would disrupt the ability of exoskeleton construction.

With no carbonate ions to build its support, seawater organisms are left vulnerable, as coral reef systems are responsible for providing diverse ecosystems for these organisms. Loss of this support system would result in horrendous imbalances of sea life.

However, it is not too late to save the coral reefs or the oceanic ecosystem, starting with reducing the amount of carbon dioxide that the ocean must absorb. Beyond that, novel solutions are being studied worldwide. Yale University proposes to grow sea plants to absorb excessive carbon dioxide. Early-stage researchers have also proposed that the amount of carbonate ions can be increased by pouring carbonate salt in the ocean. The power is within us to raise awareness and educate our world about the fragility of the ocean - an environment that we have taken for granted.

# Dredging: dunes or destruction?

BY JULIET HOINKIS, UNDECLARED, 2022

**Walking over the wooden stairs** and onto the Margate City beaches of the southern Jersey shore this past summer was sure to make vacationers and residents alike cringe. Yellow excavators, bright orange fences, and long, rusty pipelines sharply contrasted the natural serenity associated with the waves and the sand. Instead of sunscreen, the smell of gasoline filled the air. The laughter of children building sandcastles and the sounds of gently crashing waves were overpowered by the boisterous motors of tractors. Most unfortunate, however, was the sight of the ocean — no longer a beautiful shade of teal, but instead a musty black.

"Beach nourishment" is what the New Jersey Department of Coastal Engineering calls this unnatural dredging process which pumps sand from about half a mile off the coast through pipelines onto the shore in an effort to build up the dunes to protect the coastline towns against water damage from hurricanes like Sandy.

Attempting to protect the habitat of humans, however, comes at a cost to the marine environment. Dredging physically removes the foundation of the ocean floor along with the animals, plants, and bacteria who call the wet sand their home. It also increases the turbidity of the seawater, prohibiting enough natural light from reaching the vital seagrass ecosystem far below the surface. Depending on the makeup of the upset sediments, it can even reduce the amount of oxygen dissolved in the seawater at the site of dredging.

Deposition of the "new" sand onto the shore has raised concerns as well. Some Margate residents fear that the dredged sand contains increased levels of bacteria. Others are simply disgusted by the large gullies of static water that appeared between the new dunes and the bulkhead after heavy rains, creating a hotspot for bugs and contamination. The city and its redsidents went to great lengths trying halt the project, hiring lawyers, and spending hundreds of thousands of dollars hoping to convince the state that the costs of the dunes outweighed the potential benefits. They were ultimately unsuccessful.

The United States Army Corps of Engineers has completed other beach restoration projects throughout the state of New Jersey in the past two decades, but is all the time, effort, and disruption to nature worth anything?

While the dunes may provide a barrier between homes and the surf, in reality, all it takes is one hurricane for those new dunes to wash right back out to sea.

# Gliding into the future of research

BY CHRISTINA WEBER, CELL AND MOLECULAR BIOLOGY, 2020

**Drones have been very prominent** in the most recent years; we've heard of them delivering packages and capturing pictures, but what about drones going on dangerous research voyages over vast oceans, or even being shaped like a surfboard? In order to penetrate the ocean and its mysteries concerning future shifts from heat trapping gases, automatic drones, like the University of Washington's robotic surf board called the Wave Glider, have been developed.

This particular drone was sent on a mission to be the first to cross the raging waters of the Drake Passage: a 500-mile stretch channel off the tip of South America. This voyage would end up lasting four months before flaws were found. The Drake Passage is one of the few areas that has been previously under sampled for research. This is due to its "spin cycle" like surface, where winds and waves twist and turn currents and anything in its presence. These extreme conditions explain one of the main reasons why the Passage was chosen. Due to its implications for future shifts of the climate system, changing surface temperatures and wind speeds play a critical role.

A Wave Glider not only analyzes the dangerous surrounding area, but also has additional sensors to test for temperature, salinity, humidity, air pressure, and wind speed. A goal of this mission was to improve measurements of air-ocean coupling. Energy efficiency is central to its passage as it uses energy from the waves and water motion to move, as well as using solar panels to harness energy. Its wings allow it to move forward with the waves, and also prevent it to move backward, to allow for more accurate measurements.

Toward the end of the mission, the Wave Glider needed to be recharged, as there was not enough sun at one point during its journey. It could've lasted months if the sunlight was available to recharge all of its payloads. This led to the loss of data, and the need for future missions to be planned more conservatively and concisely.

In comparison to previous expenditures, this was not as costly, and was more efficient than taking a ship across the passage. One can merely control a drone while sitting in a completely different part of the world. Their upcoming analysis of new data will explore the wind-wave progression and the resulting influences of the waves on the air-ocean coupling, or exchange of heat and motion resulting in environmental climate change. It's safe to say we are gliding in the right direction.

# Clean water in developing countries

BY PAULA HORNSTEIN, BIOLOGY, 2020

**Clean water is essential** to many parts of a healthy society, from preventative measures such as hand-washing to its use in medical treatment. In the United States, we often take it for granted.

Improved access to clean water reduces the rate of abdominal infection due to water poisoning. According to the Center for Disease Control, 88 percent of diarrheal deaths are because of unsafe drinking water and inadequate sanitation facilities. 90 percent of these deaths are children under five years old.

Easily accessible safe water not only has a large impact on the health of the community but also on the social environment. According to the United Nations agency on gender, 90 percent of water retrieval is done by women, with an average of six hours per day spent fetching the water, or 16 million hours per day collectively for women studied in twenty-five African countries. When young girls are not responsible for water retrieval, and when less time is spent taking care of water-poisoned sick, school attendance increases. A Tanzanian study reported by UNICEF found that "reducing the distance to a water source from thirty minutes to fifteen minutes increased girls' school attendance by 12 percent."

Clean water projects can also greatly benefit the rest of the planet. Proper sanitation procedures and the treatment of wastewater could reduce pollution drastically. The same projects will protect biodiversity of freshwater species and reduce the impact of sub-Saharan droughts caused by climate change.

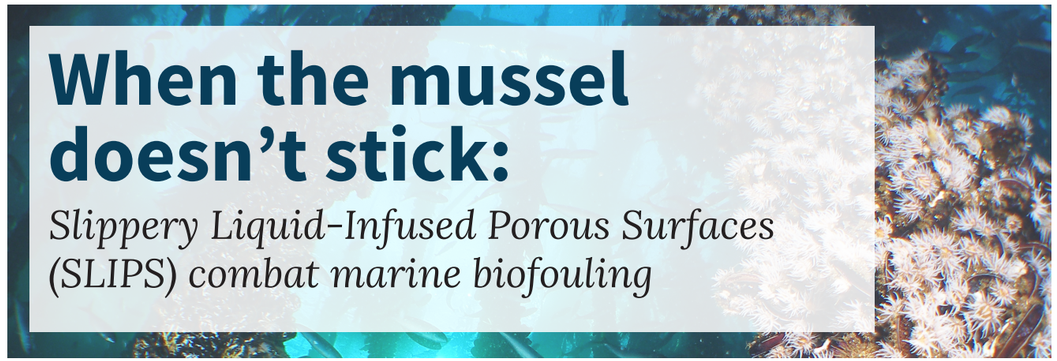
Clean water is unique in that it is necessary for most aspects of survival including drinking, nourishment, and general hygiene. Places like the rural communities of sub-Saharan Africa—and even communities closer to home, like Flint, Michigan—are still in dire need of clean, safe water.

Nonprofits, like The Water Project based out of Concord, New Hampshire, are trying to fix this. They do this by setting up pipelines and wells, instructing on hygiene and sanitation, and working on community-specific projects with local volunteers. In Kenya, in the Ngaa Community, they built a hand-dug well. In the Kivani community, a sand dam was built to prevent flooding. In communities throughout Burkina Faso, the Water Project is in the process of "well rehab" repairing and restoring wells for safe water usage.

The Water Project's goal is to provide villages with sustainable access to clean water. Sustainability is the golden rule of global health; the projects are maintained by and for the local community. That way, the community stays in control of their own health management, and water becomes an integrated part of a healthy community.

You can learn more about the Water Project and its goal of global access to water at thewaterproject.org





# When the mussel doesn't stick:

## *Slippery Liquid-Infused Porous Surfaces (SLIPS) combat marine biofouling*

BY LUCAS COHEN, BIOLOGY, 2019

DESIGN BY KRISTI BUI, COMPUTER SCIENCE, 2021

**The ocean is full of weird and wonderful creatures** – some large, others small, some swimming freely, some drifting aimlessly, and still more anchored near the surface by a series of unimaginably strong, adhesive-plaque-tipped threads. The unusually specific latter example represents mussels: bivalves known for both their resilience and their uncanny ability to aggregate in large clusters on submerged surfaces. Of course, some of these surfaces are man-made – and it's at this crossroads, where ocean meets civilization, that mussels become problematic.

Mussels can be grouped into a much larger category of organisms that spans several phyla: marine biofoulers. A marine biofouler is broadly defined as any saltwater-dwelling organism that settles and grows on submerged substrates – typically those that are quite close to the surface. It isn't difficult to imagine the substantial number and variety of man-made substrates to which this definition applies; boat hulls, floating docks, buoys, and pilings all provide ample room for space-hungry biofoulers.

Of course, this can be a major issue. The problem with biofouling is especially pronounced on ships. Though some macrofouling species might be loosely attached to the hull – like soft algae and hydroids – and therefore vulnerable to ships' movement through water, other species excrete tough outer shells and durable biological cements. Hard macrofouling species like barnacles and mussels are thus well-defended against detachment (indeed, so effective are these defenses that their shells and cements might remain long after they've died). These organisms impose significant drag penalties on the ships to which they attach, leading to proportionally significant added fuel consumption.

Accordingly, ship owners are constantly looking for new and effective ways to stop biofoulers from sticking to their vessels. In the past, biocidal paints have been a popular solution, though these are continually being outlawed as news spreads of their ecological consequences. Thus, so-called "fouling-release" solutions – which are non-toxic and prevent adhesion by subverting the mechanisms that cause adhesion in the first place – are increasingly favored.

Recent advances in materials science have proven Slippery Liquid-Infused Porous Surfaces (SLIPS) a viable solution to the problem of marine biofouling. In essence, substrates can be coated with structured, porous materials that house a lubricant; in combination, these components produce exceptionally slippery surfaces for a variety of potential applications. The technology was developed by a research group headed by Professor Joanna Aizenberg at the Wyss Institute for Biologically Inspired Engineering at Harvard University in Cambridge, Massachusetts.

In a recent paper published in Science, a cross-institutional interdisciplinary research team outlined in a multitude of experiments the effectiveness of SLIPS against mussel adhesion. In an in-situ settlement assay spanning 16 months with coated panels submerged in Scituate, Massachusetts, far fewer mussels settled on SLIPS-coated panels. Likewise, laboratory assays found fewer plaques – residues left over from attempted mussel attachments – on SLIPS-coated glass. Indeed, SLIPS seemed to drastically alter even the behavior of mussels probing for viable surfaces on which to settle.

> "SLIPS seemed to drastically alter even the behavior of mussels probing for viable surfaces on which to settle."

The team also characterized the physical forces that contribute to SLIPS' effectiveness against mussel adhesion. Indeed, mussel plaques on SLIPS had less adhesive strength, and no plaque proteins were detected on SLIPS where visible plaques were washed off. The team hypothesizes that infused surfaces – specifically, the lubricant overlayer – disrupts the mechanosensing abilities of mussel feet, which may account for the apparent inability of mussels to effectively attach to SLIPS-coated surfaces.

Though SLIPS has yet to be commercialized, SLIPS Technologies Inc., a commercial startup that formed as an off-shoot of Professor Aizenberg's research group, is working towards reaching the expansive market for marine fouling prevention.

*Science* (2017). DOI: 10.1126/science.aai8977.

PHOTO BY DAVID VILLEGAS RIOS

# There must be something in the water

*Antidepressants found in high concentrations in fish*

BY CICELY KREBILL, BIOLOGY, 2019

DESIGN BY GATES SCHNEIDER, BEHAVIORAL NEUROSCIENCE, 2021

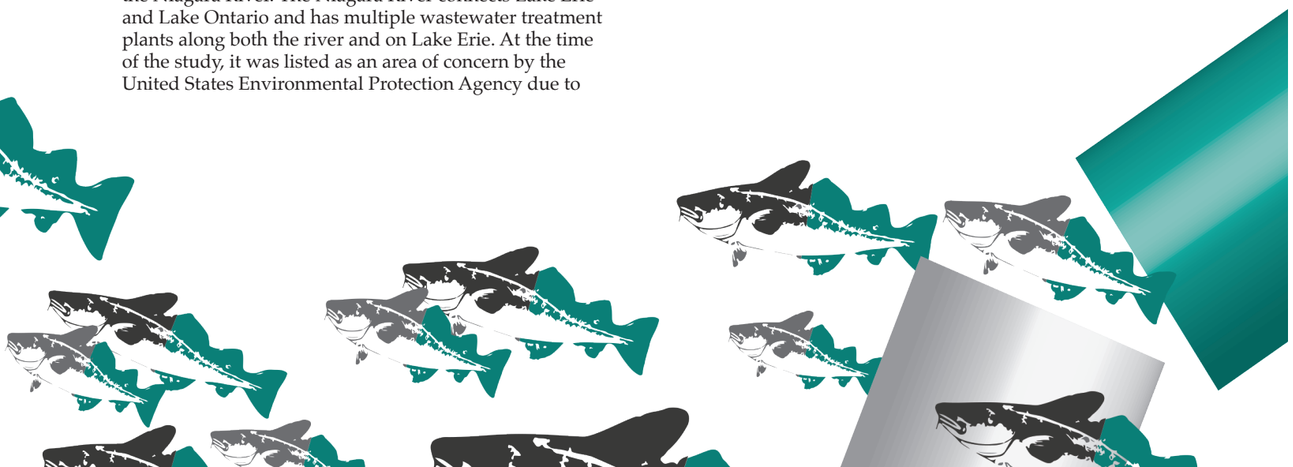
**For many years** discussion has been circulating over the vastly increasing use of antidepressants in the United States. With a four hundred percent increase in use between 1988 and 2008, the human population of the United States is becoming more medicated with these antidepressants, and with it, another unintended population is also seeing an increased exposure- the fish population. An increased use of antidepressants means an increased concentration in the wastewater. What is particularly concerning about this is that multiple studies have confirmed that the active ingredients of these medications, or their metabolites, are present in the water that leaves wastewater treatment plants. Clearly put, these antidepressants are not being completely eliminated in the water treatment plants and are eventually released back to the environment where they begin to reside in rivers, lakes, soil, and even fish living there.

These antidepressants are typically classified by how they affect neurotransmitters in the body- most frequently serotonin. Many work by blocking reuptake of serotonin to help increase its concentration in the synapse, or space between the two neurons, thus slightly changing the signal sent to the brain. In humans, antidepressants are designed to treat obsessive-compulsive disorder, depression, and panic disorder- among others in humans. These prescriptions can greatly aid the individuals that prescribe them, but the same might not be said for the fish that are inadvertently exposed to them.

Because of this there is a growing body of research being accumulated to illuminate these concerns, including a new publication from researchers from the Ramkhamhaeng University and Khon Kaen University in Thailand along with researchers from the State University of New York at Buffalo to look into uptake of antidepressants in fish from the Niagara River. The Niagara River connects Lake Erie and Lake Ontario and has multiple wastewater treatment plants along both the river and on Lake Erie. At the time of the study, it was listed as an area of concern by the United States Environmental Protection Agency due to industrial use and contamination. There they studied the bioaccumulation of pharmaceuticals in the tissues of multiple species of fish in these waters. What they found was that they were taken up by various species residing in various levels of the river. Within the species studied, the highest level of tissue accumulation of antidepressants was found in the brain, with levels in the liver, muscle, and gonads trailing behind it.

In separate studies, accumulation of these pollutants in fish has been shown to alter behavior used in population survival and community structure. This is a concern echoed by the researchers studying fish in the Niagara River. In their publication in the September issue of Environmental Science and Technology, they write “perhaps the most insidious form of environmental pollution is one that alters the behavior of the organisms in the ecosystem, which cease to act according to impulses that evolution and survival dictate”. This fear is already starting to be documented. In fathead minnows, exposure to antidepressants was shown to affect their feeding habits, growth, and reproductive system. In hybrid striped bass, change in serotonin in the brain caused by known antidepressants in its environment affected its ability to hunt. Furthermore there is concern about additional prescriptions that target the brain including antiinflammatories, analgesics, and antiseizure medications, which also contaminate aquatic habitats.

Little is known about the effects of these additional prescriptions however, they are only known pollutants presumably coming into contact with fish in the same way antidepressants are. Although it is yet to be seen exactly what concentration is needed of these active ingredients to have an effect on fish behavior one thing is clear: there is a need for improved wastewater treatment processes to help prevent this contamination.





# Plenty of fish in the sea? Maybe not.

BY FAYEZ GHAZI, BIOLOGY, 2020

DESIGN BY ANNA LI, BEHAVIORAL NEUROSCIENCE, 2018

**Did you know** that there are over 60,000 sushi restaurants worldwide? In the United States alone, the sushi industry brings in over $2 billion in revenue annually, a number that continues to grow at a steady pace every year. Half a century ago, however, hardly anyone outside of Japan knew what sushi was. The cuisine began to gain traction in the United States after the Hollywood movie star community turned the first sushi restaurant into a mainstream trend. More sushi spots sprouted across California, and after the California roll was invented in the 1970s, the industry took off.

The rise in sushi demand occurred just as new commercial fishing technologies were being developed; fish were already under threat. Throughout the 20th century advanced boats were being built to provide fisherman with the ability to capture more fish in places all over the world. Although the advancements made it effortless for fishermen to catch fish, it also made circumstances easier for them to overfish. In the 1950s, approximately 20 million tons of fish were reportedly taken out of the water every year. The number multiplied to over 80 million tons by 1988 before leveling off. Today, the global fishing industry brings in over $250 billion annually. Like most natural resources however, continuous exploitation will result in consequences. According to the United Nations Food and Agriculture Organization (UNFAO), the majority of fishing stocks are fully or overexploited beyond their maximum sustainable yields, which is the maximum level at which a natural resource can be routinely exploited without chronic depletion.

Overfishing has transformed the marine environment in numerous ways. The first, obviously, is the removal of fish, specifically larger species. There has been a significant decrease in the numbers of large predatory fish in the oceans. This is because larger fish tend to be more valuable and therefore targeted by fisherman. A prime example of this is the endangerment of the bluefin tuna. Because the species grows to over two meters in length, they reach sexual maturity at a later age. This means that commercial vessels end up targeting smaller bluefin that have yet to reproduce when they overfish. According to the International Commission for the Conservation of Atlantic Tunas (ICCAT), there were close to 500,000 tons of spawning biomass of Atlantic bluefin tuna in the 1970s, a number that shriveled down to just over 150,000 today. Pacific bluefin are even worse off. Their spawning biomass has been reduced by 96 percent due to extreme overfishing in the far east.

When populations of larger marine predators deplete, significant alterations in the food web of the underwater ecosystem occur. When an ecosystem is stable for a long period of time, larger predators evolve and feed on their smaller prey to keep them at bay. However, when the top predator of an ecosystem is removed from the equation, humans will move on to whatever fish stands next in line. This process will continue until we’ve completely fished down the marine food web and destroyed the aqua ecosystem.

> “Commercial fisheries must be subject to more stringent regulations, nationstates must abide by international rules against excessive pollution, and everyday consumers must take a stand to ensure these changes. Only then can marine life flourish again.”

Although overfishing is one of the primary causes of sea life alteration, climate change and pollution are also contributing factors. Because oceans absorb 80 percent of the excess heat in our atmosphere, their waters are warming up at an alarming rate. Warmer waters cause coral bleaching, which will result in the migration of many species in order for them to find a more optimal temperature for feeding and reproduction. The shifting of water temperature can directly impact the development, growth, and survival of most fish and cephalopods.

Despite the severity of this issue it is not irreversible. In order to regain the underwater conditions we had previously, major changes must be sustained over a large period of time. Commercial fisheries must be subject to more stringent regulations, nation-states must abide by international rules against excessive pollution, and everyday consumers must take a stand to ensure these changes. Only then can marine life flourish again.

# An unprecedented discovery:
## *Life at the seafloor*

How oceanographers discovered new life in the deep sea at hydrothermal vents

BY GWENDOLYN MCMANUS, MARINE BIOLOGY, 2022

DESIGN BY KRISTI BUI, COMPUTER SCIENCE, 2021

**In 1977, a small group of oceanographers** from Woods Hole Oceanographic Institute and Scripps Institute of Oceanography went into the eastern Pacific Ocean to look for underwater hot springs. They had aboard their ship a tiny submarine called Alvin, and its crew included Kathy Cane, a grad student, and Jack Corliss, a geologist. The team was hoping to find an explanation for some unusual deep-sea temperature data – probably originating from fissures along tectonic plate boundaries, nothing but hot water leaking from cracks in the Earth's crust. Instead, they discovered hydrothermal vents: bizarre natural chimneys rising from the seafloor, each one a towering pillar of rock that spewed a never-ending plume of superheated fluid out into the depths of the ocean. This fluid deposits minerals on the crust as it emerges, building up the chimneys in much the same way stalagmites are formed in caves.

However, these vent structures weren't the most fascinating part of their discovery. As the crew of the Alvin descended towards the seafloor, they were shocked to discover an abundance of life colonizing around the vents. These weren't just sparse communities eking out a living in the darkness; they were thriving ecosystems of everything from seven-foot-long tube worms with bright crimson tips to massive clams, surrounded by colonies of smaller anemones, crabs, bacteria, and even a few fish. There were hundreds of species, and almost all of them were undiscovered.

In a lot of ways, finding these hydrothermal vent communities was like finding life on an alien planet. The seafloor, which is on average 3600 meters deep, is very different from most other places on Earth. It's pitch black and frigid, and the pressure is high enough to crush a human being under its weight. The harsh nature of the environment means that, for the most part, very little can survive, and anything that can withstand the pressure and the temperature is still left without sunlight. Photosynthesis, the process by which plants take in energy from sunlight and convert carbon dioxide into sugars, is impossible in these conditions. For a long time, the scientific community thought there was no way for life to exist without sunlight. Hydrothermal vent communities were living proof that—somehow—this wasn't true. So where did these ecosystems get their nutrients?

As it turns out, organisms in the deep sea have adapted a process known as chemosynthesis, which is analogous to photosynthesis but relies on the unique chemistry of hydrothermal vents instead of on the energy of the sun. When hydrothermal vents form, they do so along the divergent boundaries of Earth's tectonic plates, in areas where the crust is slowly spreading outwards. As the crust expands, seawater seeps into the cooled, porous rock at the surface until it nears the rising magma. The water heats up to about 750o Fahrenheit—for reference, water boils at 212o Fahrenheit—and starts to expand and dissolve minerals from the surrounding rock, including metals like iron, copper, and lead. Eventually, it pushes back out through the crust as superheated, mineral-rich fluid. The chemicals expelled by the vents often lack carbon, a necessary component for photosynthesis and the basis of many ecosystems' food webs, so the microbes here are adapted to take in nutrients from compounds which are present, like hydrogen sulfide, ammonia, and ferrous iron. These microbes may live on their own or in the tissues of other hydrothermal vent organisms, ensuring that the entire community has access to the nutrients.

This year marks the fortieth anniversary of the discovery of hydrothermal vents, but there are many things about their role in the global ecosystem that we are still learning. One of the most valuable roles hydrothermal vent communities play may be in the mitigation of climate change, as they absorb large quantities of methane – a potent greenhouse gas – that is released by the vents. Unfortunately, drilling and mining operations at these sites threaten to upend the ecosystems. Because hydrothermal vents are hidden away in the depths of the sea, their plight is easily swept under the rug; without a concentrated effort from conservationists on an international scale, these communities may become endangered before we can even begin to comprehend their value.

PHOTO BY ETHAN DANIELS



# Venture into the unknown
## *Aliens from the abyss*

BY MATT KALPIN, MECHANICAL ENGINEERING, 2021

DESIGN BY VICTORIA PAJAK, BEHAVIORAL NEUROSCIENCE, 2021

**Nearly two hundred miles** off the coast of the remote island of Guam lies the deepest trench known to mankind, and possibly on all of Earth. The Mariana Trench is a 1,500-mile-long crevasse isolated within the western Pacific Ocean. The deepest point of the trench, Challenger Deep, was discovered in the late nineteenth century by the HMS Challenger, a warship converted research vessel. Challenger Deep extends over 36,000 feet into Earth's crust, and not even an inverted Mount Everest could reach the bottom. In fact, there would still be over a mile of water from the tip of Everest to the bottom of the trench.

There have been only four expeditions to Challenger Deep, the most recent performed by Canadian filmmaker James Cameron in 2012 when he ventured down 10,898 meters. Sunlight only penetrates down 1,000 meters, and diving beyond this point would consume you in complete darkness. Nearly 90 percent of marine life lives within the first 200 meters, above this area known as the Twilight Zone. Further down, you enter the Midnight Zone, the location of the final resting place for the HMS Titanic at 3,800 meters. Roughly 4,000-6,000 meters down is the abyss, where temperatures rest only a few degrees above freezing and pressures are 1,100 times greater than they are on land. As Cameron describes in his Deepsea Challenge movie, "literally within a minute or two I'm out of sunlight, and you're in total darkness for most of this dive, so the sub[marine] gets very cold, and you have to put on warm clothing".

One might think that it is nearly impossible for organisms to thrive, let alone survive in these inhospitable areas. However, there is a community of organisms that have adapted to these conditions, and have been shown to exhibit alien-like characteristics in comparison to most organisms. The Mariana Trench lies along a vast network of platonic activity known as the "Ring of Fire". Geothermal activity is released through numerous hydrothermal vents along the trench floor. Bacteria here have adapted to harness the energy released from the vents in the form of hydrogen sulfide, a lethal gas to humans. The bacteria fuel a vast food-chain around these vents where temperatures exceed 200 degrees Celsius. Bacteria here  have adapted to harness the energy released from the vents in the form of hydrogen sulfide, a lethal gas to humans. The bacteria fuel a vast food-chain around these vents where temperatures exceed 200 degrees Celsius.

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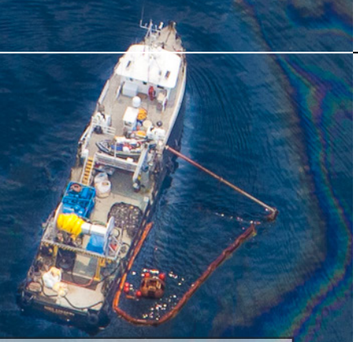
Technological advancements have allowed scientists to explore a new range of marine life and oceanic zones that would once be considered inhospitable. Most oceanic discoveries have been made by autonomous underwater vehicles (AUV's), so it is nearly impossible to identify what other marine life thrives in our oceans. Science has only recorded the deepest diving mammal, the beaked whale, at 2,992 m, so the possibility of exploration and identification of new organisms is endless. The future of discovery is, and can only be, progressed by those brave enough to venture down into the deep, dark, and unknown abyss.

PHOTO BY DIGITALBALANCE

# EVALUATING EFFECTS OF THE BP OIL SPILL SEVEN YEARS LATER

BY NATALIE MCGOWAN, BEHAVIORAL NEUROSCIENCE, 2021 DESIGN BY JAMES GOULART, , CHEMISTRY, 2021



**The news cycle** for a natural or manmade disaster is brief. We hear about the damage and the aftermath, but the story fades into obscurity as more current issues take its place. However, this pattern does not reflect reality - when the environment is involved, the effects linger long after we have forgotten about the events that caused them.

The Deepwater Horizon Oil Spill, more commonly known as the BP Oil Spill, began on April 20th, 2010 when an accumulation of methane gas caused the offshore oil well in the Gulf of Mexico to explode. Oil leaked from the well for 87 days, resulting in the worst oil spill in US history. Though the media attention and main cleanup efforts have ended, the local ecosystems and communities still struggle with the damage from the spill.

In a report recently released by Oceana, researchers discovered that bottlenose dolphins had an eight percent increase in mortality rates. In addition, the percentage of healthy offspring born decreased from 83 to 20 percent. Furthermore, researchers found that dolphins exposed to toxic chemicals off the coast of Louisiana experienced higher rates of illnesses, such as lung disease, compared to dolphins off of the coast of Florida that were not directly affected by the spill.

Two years after the spill, researchers tested eggs laid by Louisiana pelicans that had migrated to Minnesota for the summer months. They found that 80 percent of the eggs contained chemicals found in oil from the BP spill. Similarly, research studying the impact of minute concentrations of oil chemicals on fish found that they damage embryonic cardiovascular development. Bioaccumulation of these chemicals lasts over several generations and has detrimental impacts on the health of these animals.

Researchers also estimated that 600,000-800,000 birds died immediately after the spill. Not only will it take several generations for these birds as well as other species to recover from these population drop-offs, but the exposure to oil is still impacting the health of animal populations today. It's much more difficult to recover from an acute population decrease when the population that remains is less healthy. Thus, the long-term effects of the oil are arguably much more insidious than the initial deaths. Tiny amounts of oil sneak into the animal tissues and pervade the ecosystem at all levels. It's almost invisible, and almost impossible to get rid of.

Even the people living in coastal communities are experiencing long-term effects. Immediately after the spill, they reported higher rates of depression and anxiety, which stayed constant several years later. Additionally, 50,000 people involved in cleanup efforts were exposed to chemicals that have damaged their lung tissues.

The seafood industry is still hurting due to decreased fish and oyster populations; however, the economy has otherwise bounced back thanks to an ad campaign paid for by BP that helped increase tourism in the area. Furthermore, in 2014, a federal judge ruled that BP executives had displayed gross negligence and ordered them to pay 18.7 billion dollars in fines to settle federal, state, and local claims. Thus, some of this money has gone towards cleanup efforts, and some will go directly to those impacted by the spill.

Despite the results of recent studies, BP has disputed many of the conclusions reached by researchers, arguing that there is no data to support long-term impacts on a single species or that the oil residue is still toxic. The company emphasizes the tremendous recovery experienced in the region and cautions against making premature conclusions about environmental impacts.

Though five years is a short time to understand the long-term impacts of the oil spill, comparing the BP oil spill to the Exxon Valdez spill in 1989 can lend some insight into long-term effects. The results of studies performed by the National Oceanic and Atmospheric Association have shown that many animal species are still recovering from the effects of the 1989 oil spill, suggesting that it will still be many decades before the Gulf recovers from the BP oil spill.

However, there is still hope for the Gulf. While lingering effects remain, the bulk of the recovery efforts have been very successful. Many beaches that used to be covered in oil are instead filled with tourists enjoying the clean sand and water. The money from BP will also help these communities with long-term recovery. Furthermore, the spill caused public outrage, which has led to some changes in the regulation of offshore drilling.

As the public, we're not as attuned to pay attention to long-term effects because the relationship between cause and effect becomes amorphous and requires a lot of data analysis and time. The more aware we can become of these long-term effects, the more we can do to lessen the grave outcomes of these disasters.

PHOTO BY KRIS KRUG



# A diagnosis of the peril of the world of coral reefs

BY KRISHNA DAVE, CELL AND MOLECULAR BIOLOGY, 2021

**At the heart of the ocean lies** one of the most diverse and vibrant ecosystems in the world: the coral reef. Coral reefs are home to various animals including fish, crustaceans, echinoderms and mollusks. Unfortunately, due to continuous pollution and climate change, the wellbeing of coral reefs is in grave danger. Most of the heat trapped by fossil fuel emissions have been absorbed by the ocean, raising its temperature and causing harm to the reefs. To bring the severity of the situation into perspective, research shows that about 10 percent of the coral reefs are dead and about 60 percent of coral reefs are under threat due to human activities.

About 25 percent of the marine species known today rely on the coral reefs for survival. Coral reefs are essentially rainforests of the sea providing food and shelter to several species. How is this helpful to humans? According to the Hopkins Marine Station of Stanford University, coral reefs provide an estimated $30 billion annually in direct economic benefit to people worldwide in terms of sources of food, fisheries and tourism. Do we need more reasons to care? For many coastal areas, coral reefs also provide an important barrier against the worst ravages of storms, hurricanes, and typhoons. They have the ability to dissipate waves and reduce the effects of seaside erosion, aiding in the sustenance of coastal communities.

Climate change and ocean acidification is dominating marine life right now. This increased acidification is a result of the absorption of vast amounts of carbon dioxide released into the atmosphere through the burning of fossil fuels. The coral reefs, which have an exoskeleton of calcium carbonate, are imperiled by bleaching. Similarly, water pollution is a major concern for the health of coral reefs. With the increased dumping of agricultural pesticides, fertilizers, and oil spills, the erosion of the reef exoskeleton has escalated. Coral reefs also depend on zooxanthellae for their food, but with the persisting climate change and pollution, they are losing zooxanthellae, endangering them further.

Pollution and climate change aren't the only threat to coral reefs. Fishing practices such as cyanide fishing and blast fishing, which make it easier to catch fish, can destroy a coral reef very easily. These dangers have undeniably changed coral reefs over recent years.

Humans have ignored the impending doom of global warming over the years which is undeniably making organisms suffer and potentially go extinct. Coral reefs near Brisbane were investigated a few years ago at Moreton Bay. Using carbon dating, researchers concluded that branching coral became extinct in the ocean about 150 years ago. This is just one of the several species of coral reefs that has become extinct.

# The truth about rising sea levels

BY STEVE DRESEL, CHEMISTRY, 2021

**Hurricanes Harvey, Irma, and Maria** have devastated the islands of Cuba and Puerto Rico as well as areas of Texas and Florida, causing inhabitants to question the severity and speed with which climate change is impacting the planet. Flooding has been one of the most devastating aspects of these storms, bringing the question of sea level rise to the forefront of discussion on climate change. Many have heard drastic predictions that state, for example, that New York City will be underwater within the next 100 years. Climate change skeptics tend to dismiss these claims as nonsense, but the catastrophic flooding from recent storms makes it harder to do so.

So what's the truth about rising sea levels? There is no denying that sea levels are on the rise. For centuries, scientists have used tide stations to measure local sea levels. More recently, satellite laser altimeters have been used to calculate the average height of the entire ocean. By firing lasers at the earth and measuring the exact amount of time it takes for the laser to bounce off the surface of the earth and return to the satellite, they can determine the distance between the satellite and earth's surface. These tools are used to assess how much sea levels are rising over time. Between 1870 and 2000, the ocean rose about 200 millimeters. In the past 25 years alone, NASA's Goddard Space Flight Center recorded an increase in global sea levels of about 85 millimeters. The three main causes of the rise are thermal expansion, the process by which water expands when it's heated; ice melt, the slow melt of ice into the ocean; and ice loss, the loss of enormous chunks and sheets of ice. The combination of these factors has led to a rapid rise in sea levels over the past 25 years.

Flooding is only one possible consequence of increased sea levels. As seawater pushes further inland, it destroys and erodes shorelines. It also can contaminate groundwater and destroy habitats that cannot survive exposure to salty water. While there is no known link between frequency of hurricanes and rising sea levels, higher sea levels have been linked to stronger storm surges, meaning that individual storms are more detrimental.

In a world where so many aspects of the climate are shifting, it is difficult to understand a complex phenomenon like sea level rise. The exact amount of rise has been inconsistent in recent history, and there are no guarantees for what to expect in the future. Yet scientists are in agreement that sea levels have been rising and will continue to rise with increasingly severe consequences.

# NU SCI EXPLAINS WATERPROOF PHONES

BY ERICA YEE, INFORMATION SCIENCE AND JOURNALISM, 2020
DESIGN BY YECHAN YANG, PSYCHOLOGY, 2022

**Our phones are often the most expensive objects** we carry around--and probably the possessions most prone to accidents. Have you ever dropped your phone in the toilet or taken a rainy day photo to disastrous results? Here's a look at what it means for a phone to be waterproof:

First things first: No phone is actually waterproof. "Waterproof" means that water cannot get inside the phone. Instead, phones are labeled "water-resistant," meaning they can withstand a certain amount of water for a given period of time.

The common standard used in consumer electronics is the IP (Ingress Protection) rating, published by the International Electrotechnical Commission. On a scale of 0 to 6, the first number is the degree of protection against solid objects, from fingers to dust. On a scale of 0 to 8, the second number is the degree of protection against water entry, from light rain to submersion. The iPhone 7 and later models are rated IP67, meaning they can be submerged in water up to a depth of 1 meter for 30 mins. The Galaxy S8 is rated IP68, which Samsung says means it was tested submerged up to 1.5 meters for 30 minutes. But just because a phone has a certain IP rating doesn't mean it was tested at the lower standards. An iPhone 7 theoretically does not have to withstand water jets from a nozzle, as stated in a lower rating. Additionally, all IP tests are done only with fresh water, so submerge your phone in seawater at your own risk.

A recent article from technology site CNET explains some techniques used by Apple and Samsung to make phones water-resistant. The manufacturers adhere a glue-like substance to between the glass screen and the chassis, seal charging ports with rubber rings, and separate external buttons from the interior electrical parts with silicone rubber coverings.

Some third party companies have a different approach. Instead of trying to keep water out of the phone body, electronics-waterproofing company Semblant makes a nano-coating for circuit boards that acts as a barrier for water, rust, and other particles. Many manufacturers already use Semblant's technology, CEO Simon McElrea told WIRED in 2016--phone companies just don't advertise the feature so they don't have to cover waterproofness in warranties.

Ah, the warranty--both a phone owner's last hope and greatest frustration. Apple clearly states, "Liquid damage is not covered under warranty." The company also recommends users not jet ski or steam up in a sauna with their devices. Your best bet if your phone gets wet? Switch it off a quickly as possible, dab it dry with a lint-free cloth, then give it several (anxiety-filled) hours before trying to turn it back on.



# WATER BOTTLES

## THAT AUTO-REFILL

BY YECHAN YANG, PSYCHOLOGY, 2022

**Superhero and mutant related** films made thousands of people dream of creating ice crystals on the tip of their fingers. Although it is not ice, and it is not on the tip of the fingers, Funtos water bottle can make anyone a mutant with water-producing powers anywhere and anytime.

Fontus is a twenty-first century water bottle that self-refills using simple physical science. It uses a process of condensation to extract moistures in the air, allowing the bottle to refill with clean and drinkable water anywhere.

"You always have a certain percentage of humidity in the air, it doesn't matter where you are — even in the desert. That means you would always potentially be able to extract that humidity from the air," said inventor of Fontus Kristof Retezár during an interview with Live Science.

Fontus uses a solar powered condenser, along with hydrophobic surfaces and insect and dust proof filters, to purify and convert water vapors in the air to liquid water.

"Because they're hydrophobic, they immediately repel the condensed water that they created, so you get a drop flow [into the bottle]," Retezár said to Live Science.

Retezár described the "really good" condition for collecting the water to be 30 to 40 degrees Celsius for temperature, and 80 to 90 percent for humidity, where roughly 500 milliliters of water can be converted and collected in one hour.

Although the original Fontus was to be used in nature, the prototype of the water bottle is under purification system development so it can be used in more contaminated places, such as highly-populated cities.

"We're thinking about making a bottle that also has a carbon filter, and this one would be for cities or areas where you might think the air is contaminated," Retezár said to Live Science.

After the shortlisting of Fontus for the 2014 Dyson Award, the company launched crowding funding and is receiving funds from the Australian government to support the development of their water bottle.

## THAT ARE EDIBLE

BY KRITHI NATHAN, CELL AND MOLECULAR BIOLOGY, 2019

**Drinking water may become a thing of the past** with the newest conservation strategy - edible water bottles. This invention can help manage the accumulation of plastic waste and make the planet a better, more sustainable place.

In 2015 alone, the world produced 6.3 billion tons of plastic waste. Much of that plastic comes from synthetic microfibers, cosmetic microbeads, bags, and notoriously - plastic water bottles. 1,500 single-use water bottles contribute to plastic waste every second in the USA. These statistics are difficult to believe but represent the glaring state of plastic pollution in the environment.

Determined to find a solution and inspired by alginate-based "fake caviar", Pierre Paslier and Rodrigo Garcia Gonzalez of the London-based company Skipping Rocks Lab have introduced an edible water bottle named "Ooho!". It's a small gelatinous orb filled with water that consumed after drinking, quenches thirst while being eco-friendly. The water bottle itself is tasteless and produces zero waste because of its seaweed-based packaging. Seaweed is renewable, fast-growing, biodegradable, and available worldwide, making it a ubiquitous source for packaging.

Ooho! is made by dipping a block of ice in a calcium chloride and brown algae mixture. A membrane forms around the ice block, solidifying the structure while the ice melts inside, forming a water-filled orb. Ooho! is reminiscent of an organismal cell, where the cell membrane protects the intracellular cytoplasm from the extracellular matrix.

Co-inventor Paslier believes Ooho! is a step towards a packaging-free future. He states, "The problem is that a plastic bottle will take 700 years to decompose, so there's a complete mismatch between how long they're going to be used and how long the environment is going to take to decompose them. Our goal is to match the actual time it's going to take to consume, with the right packaging."

Certainly advantageous, Ooho! could be the 'bottle' of the future. It's cheaper to produce than a water bottle, costing only 2 cents per orb. It's plant-based, making it useful for people of all lifestyles. It can also contain not only water, but other liquids like fruit juices. However, there's some skepticism surrounding the hygiene of this product, though makers say the external membrane can be peeled before consuming to prevent contamination, or the orb can be consumed wholly. Furthermore, it only has a shelf life of a few days, making storage and sales not economical on an industrial scale. And yet, it's biodegradable within 6 weeks, making it a waste-free alternative.

It's difficult to say whether Ooho!, the first edible water bottle, will take over grocery stores. However, this invention stresses the importance of lessening plastic bottle use and using reusable products to contribute towards worldwide conservation efforts.

# A LOOK INTO THE EYE OF THE STORM

*This year in hurricanes*

BY SAGE WESENBERG, BIOLOGY AND JOURNALISM, 2019 DESIGN BY ANNA LI, BEHAVIORAL NEUROSCIENCE, 2018

> "It was like experiencing a blizzard where the snow could flow into your car or house. I've never seen rain pour so hard, for so long, in my entire life."
>
> – Allison Traylor, Houston resident and Northeastern '17 alumna

**This year, the news has been full of jaw-dropping moments.** At a time where disasters happen all too often around the world, natural disasters and extreme weather events have made a name for themselves in the past few months.

Hurricanes, or typhoons or cyclones as they're called in other parts of the world, are an extreme weather event of gigantic swirling clouds that leave a trail of disaster in their wake. But how do they actually come to be? Why was this such a big year for hurricanes?

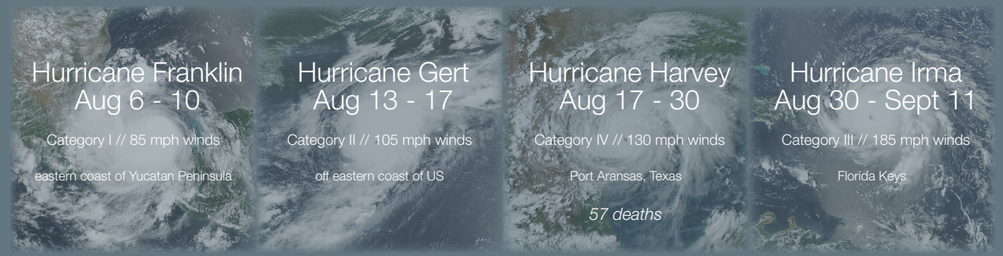
## How do hurricanes work?

Hurricanes are a form of tropical cyclones which can be formed with a simple recipe of two ingredients: warm water (minimum 79 degrees), and a steady wind that remains in one speed or direction.

Most tropical cyclones form near the equator, since they require that warmth. When air near the surface of the ocean is warm and moist, it begins to rise up, causing an area of low air pressure to swoop in beneath. As this occurs, surrounding high pressure pushes itself into the new low pressure system. This forces more warm air to rise, with surrounding air swirling around to take the place of any air that has moved up. This continues to grow in a swirling system of clouds and wind, pushed onward by the heat from the ocean and the evaporated water.

As the storm system rotates faster and faster, an eye forms in the middle, as the point of lowest air pressure, where weather appears calm and clear. Beyond the eye is the eyewall and the rainbands, containing hundreds of miles of thunderstorms and strong winds, sometimes even tornadoes. Most storms weaken when they hit land as they lose their main food source - the warm ocean waters. However, they are still capable of moving hundreds of miles inland before the stormy damage ceases. In the Atlantic ocean, the peak hurricane season runs from August to October, with several tropical storms and about six hurricanes per season.

## Hurricanes of 2017: A Summary




## The perfect storm

**Category 5 hurricanes** are fragile storms to maintain, but extremely dangerous. A Category 5 storm has the potential to do 500 times more damage than a category 1 storm. These storms can only occur if winds exceed 155 miles per hour, and remain near warm water of about 80 degrees, away from wind shears that can break up the hurricane's rotation, and able to avoid large islands that can cause the hurricane to lose strength. In the case of Hurricane Irma, its surrounding water was a balmy 84-86 degrees, and there was very low wind shears, helping it to be one of the four hurricanes to make landfall as a Category 5 storm since 1924.

### The Saffir-Simpson Scale

| category | wind speed (mph) | damage | storm surge (ft) |
|---|---|---|---|
| I | 74 - 95 | minimal | 4 - 5 |
| II | 96 - 110 | moderate | 6 - 8 |
| III | 111 - 129 | extensive | 9 - 12 |
| IV | 130 - 156 | extreme | 13 - 18 |
| V | 157+ | catastrophic | 19+ |

## Is climate change involved?

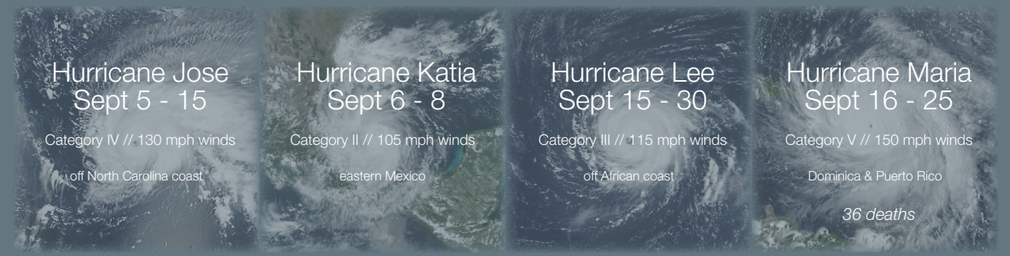
**Many scientists and concerned citizens** are wondering whether climate change is to blame for the uptick in severe storms and damages this season. From 1981 to 2010, there have been an average of 12 named storms and six hurricanes. This year, NOAA predicted an increase, with 14-19 named storms and between five and nine hurricanes.

This season has been particularly active for several reasons, some of which may be attributed to climate change. In seeing warmer temperatures globally, the oceans are seeing warmer surface sea temperatures than usual. Years without El Nino, like this year add to hurricane-friendly conditions. A higher thermal potential for the Atlantic ocean helps water to more quickly evaporate into the atmosphere, leading to more powerful hurricanes. Years with El Nino drive a warmer equatorial Pacific but also more wind shear, which gives overall less thermal potential to the Atlantic.

Hurricanes Harvey, Irma, and Maria all broke records as they gained immense amounts of strength incredibly fast, and dumped record breaking amounts of rain over short periods of time. While scientists are very hesitant to make estimates of climate change's causality to these extreme weather events, globally rising average temperatures are causing the increase in rainfall. Air is capable of holding seven percent more water for every celsius degree up in temperature. So as both air and water get warmer, there is more fuel for hurricanes. As heat energy is dissipated from the evaporated water, more rain occurs. These extremely high rain levels also cause more damage due to increases in construction in coastal communities, larger storm surges, and sea level rise from global warming. As the 2017 hurricane season comes to a close, scientists and climatologists will be publishing many research efforts with the results from this year's storms. Hopefully their findings will bring more clarity to the impact that climate change is having on these storms.

## A look back on the stormy season

**These past few months** have made for a record breaking year in hurricanes, and the United States is busy picking up the pieces of the aftermath. Notably, Hurricane Harvey hit Texas hard with over 60 inches of rain at its peak, and over 27 trillion gallons of water overall, making it the wettest storm in history. With over 75 fatalities and $180 billion in damages, Texas had only begun to pick up its mess when Hurricane Irma hit the Caribbean, Puerto Rico, and Florida as a Category 5 storm With winds over 185 mph and 10.8 inches of rain per hour, Irma took the books as one of the strongest hurricanes ever recorded. Most recently, Hurricane Maria wiped out Dominica and Puerto Rico as a Category 4 storm. 150 mph winds reached out 230 miles from the eye, knocking out 80 percent of Puerto Rico's power, which will take months to repair. These cities will be working to recover their buildings, shorelines, and homes for many weeks to come.



# Waterworlds: I want to believe

BY SAMANTHA GLASSNER, MECHANICAL ENGINEERING, 2020

DESIGN BY KRISTI BUI, COMPUTER SCIENCE, 2021

**Many ponder the idea of extraterrestrial life** coming and invading Earth in UFOs but NASA scientists are trying to make the first move. Knowing our own origins, they are following the water and looking for Earth-like celestial bodies that could support life. In this quest, NASA has discovered a promising location where other life could exist in our very own solar system: one of Jupiter's moons named Europa!

Back in the 1990s, NASA's Galileo mission to Jupiter discovered strong evidence that the moon Europa could have a liquid ocean beneath its icy exterior. Europa is approximately the size of Earth's moon but if it does in fact have a salt water ocean, it could contain more than double the water that is in Earth's oceans. This discovery got NASA scientists extremely excited because with hope of water comes hope of life. Therefore, NASA has begun to further investigate the habitability of Europa.

Additional evidence was collected by the Hubble Space Telescope, which reported large plumes, or tall columns of suspected water vapor, erupting from Europa. Researchers speculate that these recurring plumes are caused by water erupting from within Europa. The locations of the plumes are linked to warm spots identified in a thermal map created by the Galileo mission, leading researchers to hypothesize that the hotter temperatures in that area could be warming the surrounding surface of the icy crust and allowing the liquid water below to vent.

Further investigations of this Jovian moon involve endeavors like creating a model of the conditions of Europa to determine its chemical energy balance and if it is likely life-sustaining. Scientists at NASA's Jet Propulsion Laboratory (JPL) focused on gathering data on Europa's proportions of different life-supporting elements. One of the focuses of this study was comparing Europa's ability to produce oxygen and hydrogen because they are important elements that are the building blocks of water. Water, or H2O, is a molecule formed by the joining of two hydrogen atoms and one oxygen atom. Interestingly, in 2016 JPL scientists found that oxygen was produced about 10 times more than hydrogen on both Earth and Europa. This discovery makes scientists hypothesize that even if Europa does not have volcanic hydrothermal activity it may still have the chemical energy balance needed to support life. While NASA scientists continue making observations from afar new missions to make a deeper dive closer to Europa are in the works.

NASA has a new mission planned for the 2020s called the Europa Clipper to further investigate this water world and its potential habitability for extraterrestrial life. This mission plans to do about 40 to 45 flybys of the moon. Each flyby would involve taking high resolution photographs of the surface and data from many scientific instruments about the composition of the moon. In a recent NASA update on March 9, 2017, one of the Europa Clipper project scientists, Robert Pappalardo, of the JPL, explained that, "During each orbit, the spacecraft spends only a short time within the challenging radiation environment near Europa. It speeds past, gathers a huge amount of science data, then sails on out of there." The focus of this mission will be to determine if Europa has the requirements for life: water, energy sources to enable biology, and chemical ingredients.

Europa is not alone in its status of promising water worlds; NASA's missions are constantly searching for strong candidates for life-sustaining bodies beyond our planet. Recently, the NASA Cassini mission to Saturn also shed light on one of its moons, Enceladus. Cassini scientists were able to gather data on Enceladus and found that liquid water may lay under its icy exterior. New discoveries of water worlds like Europa and Enceladus heighten the chance that soon, with further scientific exploration, we will finally know if we are alone in this universe.

PHOTO BY NASA



# Our next storage solution

## *Can we store excess $CO_2$ in deep sea trenches?*

BY ZIFISO NYONI,CHEMISTRY, 2019

DESIGN BY YU CHENG, INFORMATION DESIGN, 2017

**Google Earth is typically used** to explore new cities, traverse foreign landscapes, or perhaps look at a 3D image of the new pizza place down the block. However, New Zealand energy analyst Steven Goldthorpe has used the software in a quite different way, to explore potential locations for underwater carbon dioxide (CO2) lakes. In recent weeks, Goldthorpe has proposed that CO2 could be pulled from the atmosphere and stored permanently in enclosed basins on the very deep ocean floor in an effort to mitigate the effects of CO2 as a greenhouse gas. Goldthorpe, using the most advanced version of Google Earth, pinpointed storage location candidates across the globe using criterion according to conditions optimal for CO2 to exist as a liquid or solid. With increased atmospheric pressure at 5.1 atmospheres (or 75 pounds per square inch) and temperatures below -56 °Celsius, CO2 can exist as a liquid. Furthermore, its density under these conditions is greater than seawater, and could remain permanently as a lake of liquid CO2 on the ocean floor with the possibility of becoming a solid over an undetermined time length.

Based on these factors, locations that were targeted include the Sunda Trench (south of the Indonesian Archipelago), the Ryukyu Trench (700 km from the Chinese coast in Japanese waters), and the Puerto Rico trench. According to Goldthorpe, the Puerto Rico trench has a carrying capacity of "24,000 gigatonnes of liquid CO2 deeper than 7 km." This one trench alone is large enough to hypothetically store all CO2 emissions dating back to 1850, plus future estimated emissions from all known privately and government owned fossil fuel reserves.

As of recently, leading candidates for carbon sequestration are mineral carbonation, a process in which CO2 is reacted with metal-oxide bearing materials to form carbonates and solid byproduct such as silica, and geological storage, a method that involves injecting carbon dioxide directly into underground geological formations. However, limited storage capacity, risks of carbon leakage, difficult monitoring conditions, and inefficient economics has led to questions regarding optimal storage procedures and locations to be inquiries with limited discernible answers.

Underwater storage, as opposed to other techniques, provides the opportunity to easily monitor CO2 levels with autonomous or remotely controlled submarines. Nature itself seems to support the sentiment of such deep-sea carbon pools, as a naturally formed lake of CO2 was discovered deep in the East China Sea, canopied under a sheet of sediment.

Similar to the naturally occurring lake found in the East China Sea, artificial deep ocean CO2 pools would also need a physical barrier to keep the liquid trapped. Emphasizing this point is an experiment performed by a group of Stanford University researchers in 1999, which involved bringing a beaker of liquefied CO2 to a depth of around 3,600 meters off the coast of California. The CO2 was recorded as expanding and spilling over into a snowy hydrate around four times its original liquid volume. An occurrence such as this on a scale of Goldthorpe's proposal could be costly, as CO2 reacts with water to form carbonic acid in a composition that could increase ocean water acidity. Higher ocean acidity could lead to the dissolution of calcifying organisms such as coral, clams, mussels, sea urchins, barnacles, and certain microscopic plankton as they depend on equilibrated chemical conditions and pH levels in the ocean.

However, the greatest concerns regarding the idea of deep ocean CO2 pools (along with other carbon storage options) are logistical. Deep ocean trenches suited for CO2 storage are located far away from the power sources that produce exorbitant amounts of CO2. Goldthorpe elicits a situation in which tanker ships would bring pressurized CO2 to barges in the ocean; and from these barges, the gas could be pumped through pipes into a sea trench. An alternative method could be a network of undersea pipes running from power stations into the sea. However, the process of containing, liquefying, and shipping CO2 (regardless of the method) would result in crippling costs for power utility companies.

The general consensus, including Goldthorpe himself, acknowledges that significantly more research has to be conducted before serious consideration of using underwater CO2 lakes as a viable carbon sequestration strategy. However, discussion of the topic is not for naught. As Franklin M. Orr, a lead collaborator from the 1999 deep dive experiment discussed above, observed with great foresight at the time, "the prudent thing to do is to have the research base in place so that policy makers, when they're ready to deal with this question, actually can do so."

*Energy Procedia* (2017). DOI: 10.1016/j egypro.2017.03.1686
*GeoScienceWorld* (2008). DOI: 10.2113/gselements.4.5.319

PHOTO BY FLICKR

# How much energy does it take to make a burger?

ARTICLE AND DESIGN BY ANNIE LEE, DESIGN, 2019

**A 1/3 pound burger requires:**


**600 gallons** of water

**64.5 ft²** of land

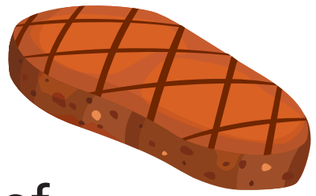
**0.126 pounds** of methane $CH_3$

**4lbs** total carbon footprint

Below is the general process of producing a beef patty.

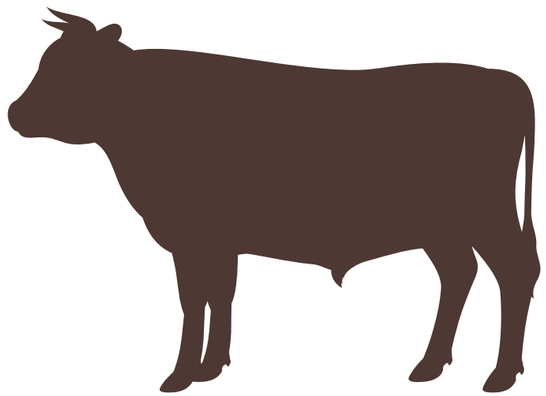


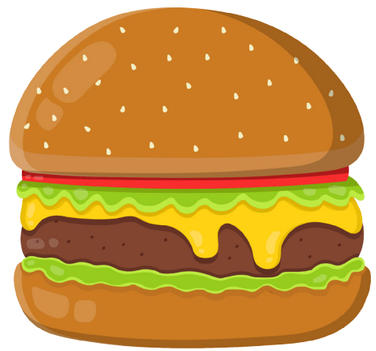

Most of the water used to make a burger is for producing beef.



**1800 gallons** of water for

**ONE POUND** of beef





> “40 percent of all rainforests have been cleared or burned down in the last 40 years mostly for cattle pasture to feed the export market – often for US beef burgers…”
> — John Revington in World Rainforest Report

The US could reduce the food-related water footprint by 36 percent if people switched to a vegetarian diet because consuming crops is more efficient in conserving water and energy than consuming beef. Livestock production may have a larger impact on climate change than you think. According to a study from Oregon State University and Loma Linda University, the U.S could hypothetically come close to meeting Obama’s 2020 greenhouse gas emission goals (ghg) if everyone in the US eliminated beef from their diet. Specifically, if beans and legumes were replaced for beef, the US could achieve approximately 46 percent to 74 percent of the reductions needed to meet the 2020 ghg goal. Another alarming effect is the large quantity of land required to produce beef. In total, the United Nations estimated that a one third of the land on Earth is used to produce meat and animal products.

In the grand scheme of things, it’s unlikely that everybody will stop eating burgers. Meat consumption is an inherent part of culture. And in developing countries, people are dependent on meat as their main food source. However, for industrialized countries where food is a surplus, a dietary change or even just opting for a vegetarian option for a meal can make an impact.

*Water Footprint* (2007). doi.org/10.1007/s10584-017-1969-1
*Animal Frontiers* (2014). Ndx.doi.org/10.2527/af.2012-0038

# The future of cancer treatment: FDA approved

BY ADRIANNA GRAZIANO, BIOLOGY, 2019

DESIGN BY KYRA PERZ, CHEMISTRY, 2020

**Cancer immunotherapy, a process** that involves genetically modifying a patient's own immune cells to fight cancer, has received its most rewarding breakthrough to date. This past summer, Novartis' CDL019 chimeric antigen receptor (CAR) T-cell therapy therapy, coined KymriahTM, was unanimously approved by the FDA to treat B-cell Acute Lymphoblastic Leukemia (ALL) in children and adolescents ages three to 25.

> "Unanimous FDA approval set a precedent that paves the way for more gene therapies."

This treatment is life-changing for many in the patient population it targets - those with refractory or relapsed ALL. After exhausting front-line options, including chemotherapy, radiation, and stem cell transplants, these refractory or relapsed patients have a five-year disease-free survival of less than 10 to 30 percent. Optimistically, Novartis' KymriahTM therapy demonstrated a promising 83 percent overall remission rate in the clinic, saving and extending the lives of patients with such limited options.

However, the use of CAR T-cells hasn't come without risks. Once the patient's T-cells are collected and engineered to express a cancer-specific chimeric antigen receptor (CAR) on their surfaces, the T-cells are reintroduced into the patient's body with the ability to recognize and kill cancer cells with specificity. This reintroduction stimulates the immune system and can cause it to become overactive, toxically increasing secretion of proteins called cytokines that can cause high fevers, organ damage, and potentially death. Of course, this is a potential risk with all immunotherapy approaches, and symptom management has become a priority within this field.

Perhaps the most significant decision in this FDA approval is that this therapy involves genetically modifying immune cells using a viral vector whose long-term effects are unknown. There is cause for concern from researchers that the integration of vector DNA into the body may eventually become mutagenic and thus potentially create harmful and cancerous T-cells. However, the unanimous FDA approval set a precedent that paves the way for more gene therapies that are set back by this potential risk to gain approval.

Despite the risks and challenges of cancer immunotherapy, Novartis has demonstrated what effective treatments can look like for patients without many options. All eyes will be on this therapy as it becomes an FDA-approved drug, and hopefully more approvals will follow in the life-saving field of research that is cancer immunology.

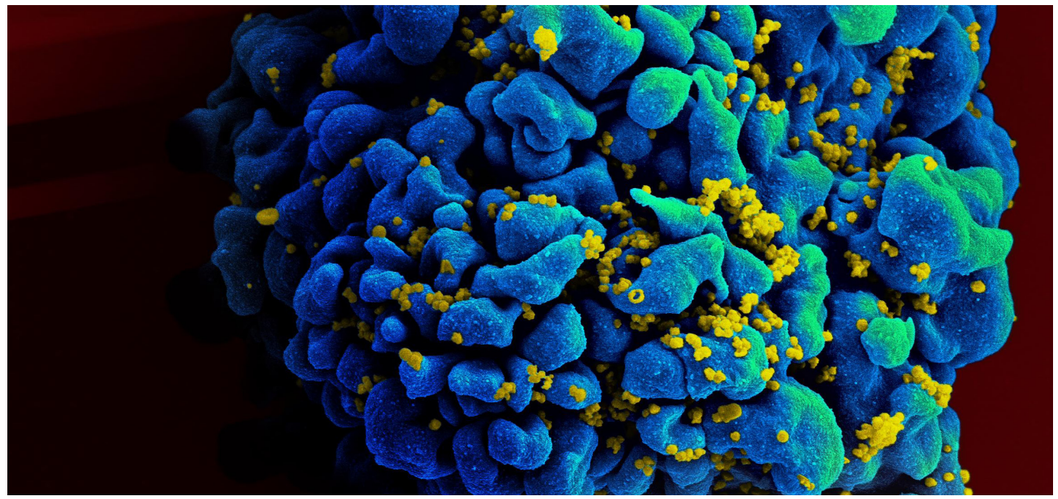


PHOTO BY WIKIMEDIA

# Autopsy of a quantum computer

BY JAMESON O'REILLY, PHYSICS AND MATH, 2019

DESIGN BY KYRA PERZ, CHEMISTRY, 2020

**The lead sentence of this type** of article typically makes an outlandish yet ambiguous assertion about the limitless potential of quantum computers, especially regarding the specific "breakthrough" that the article is about. Generally, this is the end of the "lead" paragraph, which is supposed to convince the reader to keep going while also summarizing what the article is about. Unfortunately, it also sets a precedent of vague, misleading characterizations.

Almost invariably, the author starts by pointing out that unlike classical bits, which exist as either a 0 or a 1, quantum bits can be both at the same time. This definition of quantum bits (qubits) is at best an oversimplification. It is true that a so-called qubit can be in a superposition of its 0 and 1 states, in addition to being simply one or the other, but saying that they are a combination of the two does not capture the full situation.

A fuller, more honest explanation could start by mentioning that quantum mechanics is a more general version of classical probability theory. Rather than each possible outcome of an observation having a probability, each state a qubit can inhabit is assigned an "amplitude" whose square represents the probability that the measurement will find the qubit in state. In classical probability theory, the probabilities of all possibilities must add up to 1. In a quantum setting, there is only the looser requirement that the squares of all the amplitudes add up to 1. This allows for negative and complex amplitudes, which cause strange phenomena like destructive interference and entanglement.

> "A fuller, more honest explanation could start by mentioning that quantum mechanics is a more general version of classical probability theory."

Once the article establishes the what, it can move on to the why. If any explanation beyond evoking the spooky phrase "quantum mechanics" is given for the supposed power of these new machines, it is usually something about trying every answer simultaneously or using exponentially many states. The former is based on the multiverse theory espoused by, among others, David Deutsch, one of the most important pioneers of quantum computation. Proponents of this explanation claim that all the computations must be done somewhere, specifically in other universes. While this theory has some powerful advocates, it is hard to test and far from being universally accepted.

The latter is somewhat correct but ultimately too vague to provide a full understanding. It's true that the number of complex numbers needed to describe a collection of n qubits is 2n and thus grows exponentially with the numbers of qubits. For example, a system of two qubits has amplitudes for 00, 01, 10, and 11. However, it is not completely clear yet how much this contributes to the quantum advantage over classical computers. It certainly seems to help with simulating quantum mechanics, giving it the potential to help develop new medicines and design new nano-devices, but it is still unclear how general of an advantage this is.

Now is generally when the researchers get to speak about why their work is important and interesting. It is perhaps telling that the reader does not get to hear from the scientists directly until this point. Given their deep understanding of the subject matter, the scientists should be able to give better explanations for the power of quantum computing. The journalist may not ask if they are worried that they or their audience will not understand, but they fail to realize that the scientists did not understand at first either. Replacing real science with hand-waving just widens the perceived gap between scientists and laypeople. Nobody truly understands quantum mechanics in the usual, intuitive sense of the word, but they can use the mathematical formalism to draw conclusions. That takes years of hard work for anyone.

Then again, the recycled clichés passed from one article to the next must have come from somewhere. It may be that the scientists themselves are unwilling or unable to provide accurate descriptions of the physics underlying their work. This is a profound failure on their part to meaningfully engage with the public and conduct their work responsibly. Communication skills like these must be included in graduate training to fully prepare students to be effective scientists.

The article usually ends by reaffirming the limitless potential of quantum technologies, possibly invoking a second computer-led revolution. There is no mention of the fact that only very specific applications stand to gain. Quantum computing may change the world, but it may not. It may never work at all or it may only be available to the wealthiest corporations. Nevertheless, promising a useful quantum computer in the next five to 10 years is a proud tradition of the last three decades.

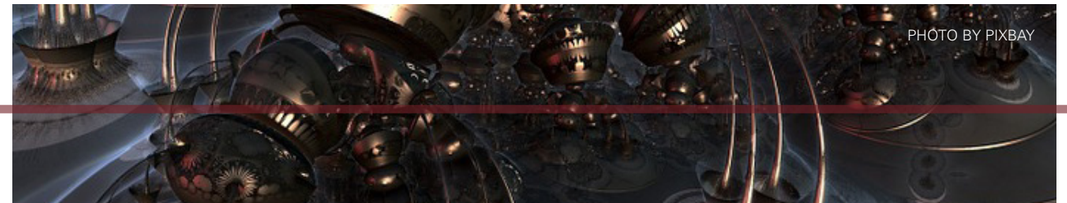
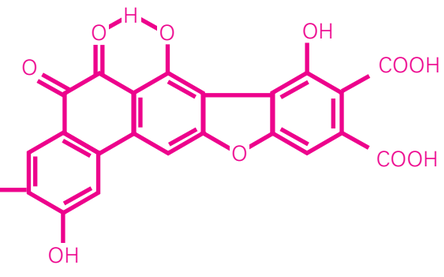


PHOTO BY PIXBAY

# Northeastern's Own Organic Breakthrough

By Lucas Principe, Environmental Science & Philosophy, 2020
Design By Lillie Hoffart, Environmental Science, 2022



**Researchers at Northeastern University,** in partnership with the Organic Center, a nonprofit research and education organization in Washington, D.C., have just published a significant finding in the arena of agricultural practices and carbon sequestration. They have reported that soils from organic farms store more carbon, and for longer periods, than typical agricultural soils.

Organic farms, which are certified by the USDA, differ from conventional farms in many ways. First, their soils cannot have contained prohibited substances, such as synthetic fertilizers or pesticides, for three years prior to harvest.

Additionally, organic farms cannot grow or handle food containing genetically modified organisms. Organic farms are also inspected thoroughly to check for USDA regulations which pertain to water systems, pest management, contamination risks, and many other categories.

The project, nine years in the making, was recently published in the major journal Advances in Agronomy under the title "National Comparison of the Total and Sequestered Organic Matter Contents of Conventional and Organic Farm Soils."

Northeastern's Drs. Geoffrey Davies and Elham Ghabbour co-led this almost decade long project to analyze soil from every corner of the nation to discover its components and properties. When asked about how the idea for this project first occurred to them, Davies said it was in 1993. He had been working on a project involving zeolite catalysts at the time when Ghabbour, a postgraduate researcher from Egypt, approached him with an idea to research humic substances, the focus of this most recent study. Upon hearing this proposition, Davies said, "I dropped my catalyst work and we just dove right in." He then added, "She (Dr. Ghabbour) deserves all the credit in the world for this idea."

The main finding contained in this study is the crucial role of organic soil in carbon sequestration. The study finds that, on average, organic farms have 44 percent higher levels of humic acid, 13 percent more soil organic matter, and 26 percent greater potential for long term carbon storage.

This unique study dealt extensively with humic substances, a topic that Davies and Ghabbour have been researching for over two decades now. Humic substances, the major sequestered organic components of soil, as shown by radiocarbon dating. They are vitally important to sediment health because Davies says they "sit in the soil and confer many valuable properties such as helping to retain water and also controlling the climate because of the high thermal capacity of water," among other attributes. These materials are so important in carbon sequestration because "they're made of carbon and have lifetimes of hundreds and thousands of years," he continued. Hence, a higher level of humic substances in a soil means that more carbon is present.

So why do conventional farm soils contain less humic substances than organic soils? "First of all, most conventional farm soils are tilled, and that means the air can get at the organic substances," said Davies. Other factors include three crops planted each year instead of two, which leads to depletion of soil nutrients, and inorganic fertilizer overkill, principally from the application of ammonia and ammonium nitrate.

The study was quite broad-ranging, and involved a relatively new research approach: enlisting the help of "citizen scientists". Over 1000 soil samples were collected and mailed in by hundreds of volunteers throughout 48 states. Each sample was then analyzed on campus at Davies' and Ghabbour's lab in Hurtig Hall. The soil samples each took nine days to analyze, and these analyses were running for nine years with the help of seven Northeastern undergraduate co-authors of the study.

Now that we know organic soil sequesters more carbon than conventional soil, it would be no surprise if the demand for organic products increased. Consumers who vote with their dollars can now take even greater climate action at their local grocery store. About this premise, Davies added, "If everyone starts converting farms over to organic, the rate of carbon capture will be that much faster. Soil is by far the largest carbon sink."

With a claim this revolutionary, follow-up studies will inevitably be conducted in the following years to cement this finding. However, Davies is keen about other researchers doing so, and does not seem to be very concerned about the skeptics, stating "Other people might be skeptical about what we've found, although on this scale it's hard to refute."

You can find the full study, "National Comparison of the Total and Sequestered Organic Matter Contents of Conventional and Organic Farm Soils", authored by Ghabbour, Davies, members of The Organic Center, and others, published the first of October on page one of Advances in Agronomy.

*We at NUSci would like to thank Dr. Davies for his continual support of our publication. We are grateful for your encouragement, vision, and expertise as our club advisor, and we congratulate everyone involved in the completion of this nine-year project.*

*Advances in Agronomy* (2017).
DOI: 10.1016/bs.agron.2017.07.003.

# Fulbright scholar fulfills big dreams on a small scale

ARTICLE AND DESIGN BY GWENDOLYN SCHANKER, JOURNALISM AND BIOLOGY, 2018

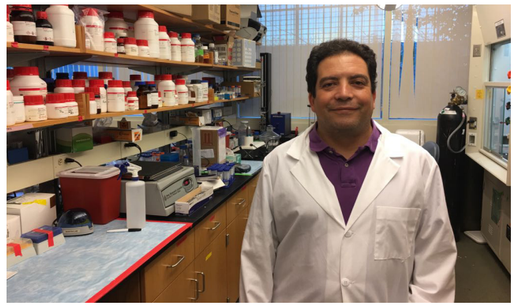
PHOTO BY GARCIA MARTIN

**Interdisciplinary collaboration** and global experiences are two of the key reasons that students are drawn to Northeastern University. Though José Miguel García Martín is not a Northeastern student, throughout the past few months, he has embodied both of those goals.

García Martín, a research scientist at the Institute of Micro and Nanotechnology at the Spanish Research Council in Madrid, Spain, spent three months in Northeastern Professor Thomas Webster's Nanomedicine Lab studying the antibacterial properties of nanostructured coatings.

Webster, who is also the department chair in Northeastern's chemical engineering department, has spent his prolific career exploring the possible applications of nanotechnology. Like García Martín, his primary interests lie in the biomedical field.

García Martín first discovered the potential for a collaboration with Webster when he visited Boston two years ago as an awardee for the IDEA2 Madrid program, which was designed to help aspiring biomedical researchers in Madrid share and develop their ideas. It was during this trip that he heard about Webster's lab and the goals he and Webster share. The next step was to apply for a Fulbright Scholarship so that he could further explore those goals.



*García Martín in the lab at Northesatern.*

"In nanotechnology, collaboration is essential," García Martín said. "We have to face problems from different points of view. Searching for good people with complimentary know-how is essential."

Ultimately, García Martín hopes to use nanotechnology to develop orthopedic implants, which can be used to replace a damaged or missing joint in the body. Implants are an amazing tool in the medical field, but can often cause bacterial infection. Antibacterial resistance is therefore an essential component of the nanostructures that will eventually be used to make these implants.

While at Northeastern, García Martín's primary task was to test the antibacterial properties of the coatings that he has developed – more specifically, to test the effectiveness of those coatings against gram-negative bacteria.

Webster and García Martin use different techniques to develop nanorods, a physical form of nanomaterial: Webster uses chemical nanorods while García Martín uses physical nanorods. García Martín found that combining his own material with the nanorods being developed by Webster's team produced a highly successful result. "The antibacterial behavior is enhanced when the two nanostructures are combined," he said.

This is an exciting stride forward in García Martín's more than 20-year career. There is still a long process ahead before the nanostructures Webster and García Martín have developed can begin to be implanted in humans, but García Martín is confident that their low-cost approach can be successfully scaled up to mass production.

García Martín headed back to Madrid at the beginning of October, but plans to continue his collaboration with Webster's team by continuing to work with Webster's Ph.D. student David Medina, whom García Martín worked alongside throughout his months at Northeastern. García Martín will provide samples from Spain as researchers in Webster's lab continue to explore the utility of nanostructures in making orthopedic implants, as well as possible other applications in cancer and regeneration research.

García Martín has always appreciated the process of scientific research, especially when it gives him the opportunity to collaborate with researchers around the world. He encourages aspiring scientists to pursue global experiences like the Fulbright Program. "In the complicated world we're living in, it's good to see how other people live," he said.

He also stresses the importance of scientific outreach, especially in a country like Spain, where he says much of the general public does not show an interest in science. For that reason, he has participated in a variety of outreach activities in Spain. This included a prize in an image contest in 2016, where he submitted an image that was captured through magnetic microscopy and demonstrates what García Martín refers to as "the beauty of the nanoworld."

García Martín enjoys every stage of scientific research: from the spread of ideas to the thrill of discovery to the value of sharing what he's learned with audiences both at home and abroad. "I think we have to give back to the community and give them hope that we are using well the funds we are receiving," he said.

300nm Scanning Electron Microscopy (SEM) image courtesy of CSIC

Faculty Q&A:

# Dr. Randall Hughes

Associate Professor, Marine and Environmental Sciences Department

BY LUCAS PRINCIPE, ENVIRONMENTAL SCIENCE, PHILOSOPHY, 2020
DESIGN BY LILLIE HOFFART, ENVIRONMENTAL SCIENCE, 2022

**Dr. Randall Hughes** has been a professor in the Marine and Environmental Science Department here at Northeastern since January of 2013. She teaches classes such as Marine Biology and Conservation Biology, and is currently developing a new disease ecology class. Her research interests include marine and estuarine diversity and conservation, and she has quite a diverse background in both teaching and research. I sat down with her at the end of September to talk about her research, teaching career, and many other marine related issues.

**LP: Why did you decide to pursue research relating to marine biology, conservation and diversity?**

RH: As an undergraduate I was a biology and public policy double major. I really liked science but I also wanted to apply it and have a conservation impact. During undergrad, I decided I needed to focus on science if I was going to do any environmental policy effectively. So, I worked as a research assistant at University of North Carolina's marine lab, received my first straight research experience and fell in love with it. I then went on to grad school and stayed with the straight science path for a while; just in the last few years, especially since arriving at Northeastern, I've now been trying to bring in those conservation interests again and do some more applied work.

**LP: Can you talk about some of the research projects you have going on right now?**

RH: We're working primarily in three different coastal habitats: seagrasses, oyster reefs, and salt marshes. In both the sea-grass and the oyster reef systems we have parallel projects going. We know that genetic diversity within seagrasses and oysters can make them more productive and can increase their ability to respond to various stressors. One of the most increasing stressors in the ocean is disease. Both eelgrass, the primary seagrass species we have here, and oysters are prone to diseases. These projects aim to look at the relationship between genetic diversity and disease. We're trying to see if more genetically diverse populations have reduced disease prevalence. Or, because genetic diversity tends to increase species density and abundance, and that tends to lead to increased disease spread, there could actually be a positive relationship between diversity and disease. We don't really know yet which pathway is going to win out.

**LP: You talked about increased marine disease prevalence earlier, do you have any idea why there has been an increase as of late?**

RH: It's probably a couple of things. One, we're paying more attention, there's more people out there looking around and studying these ecosystems. But two, we know the environment is changing, at least with the sea-star wasting disease that has received a lot of attention on the west coast it's thought that maybe rising ocean temperatures or changes in ocean chemistry can be playing a role in facilitating disease.

**LP: Tell us about what it's like working at the Marine Science Center in Nahant.**

RH: Well, the growth of the MSC is one of the factors that drew me here. The university really had a lot of vision to invest in that facility when other universities were cutting similar types of programs. There's a great energy and collaborative environment; and we're still continuing to grow.

**LP: I understand you used to teach seventh grade science, do you believe that experience in patience helps you in a university setting?**

RH: Well, I may have not had enough patience, since I went back to graduate school. I knew I was interested in science, but also wanted to try my hand at teaching before going back to school. The level of the content may vary, but the ability to reach your audience stays the same whether you're talking about seventh-graders, undergraduates, or even the public.

**LP: Any advice for students pursuing degrees in marine related fields?**

RH: The best thing students can do is get some research experience. Often students start off with a very broad interest. Doing research helps you hone these interests down. Seeing what day-to-day research is all about, whether that's what you go on to do or not, is an important first step.

## Classes Taught by Dr. Hughes

- Conservation Biology
- Marine Biology
- Research at the Marine Science Center

PHOTO BY NITHIN SARIPALLI

# Researchers wanted: Apply here!

## Four Northeastern students, four exciting summer research projects

BY RAFI RAZZAQUE, ENVIRONMENTAL SCIENCE, 2019

DESIGN BY JULIE MURMANN, BEHAVIORAL NEUROSCIENCE, 2021

**Where did you go this summer;** somewhere fun, hopefully? Did you successfully manage to balance academics and travel?

For several Northeastern students, they found the exciting opportunity to travel for research positions across the US while also being compensated for their work. Their Research Experiences for Undergraduates (REUs) gave them the opportunity to scope out the caves of central Texas, examine the volcanic formations of Hawaii and dive into the shores of Southern California.

To facilitate their research, REU students are flown out to the host university and compensated with room and board; these National Science Foundation-funded programs give undergraduates the chance to apply themselves to exciting lab and field research opportunities backed by financial security.

The details for four particular Northeastern students who participated in REUs this summer are outlined here, to inspire fellow students to reach for the exciting opportunities in their field!

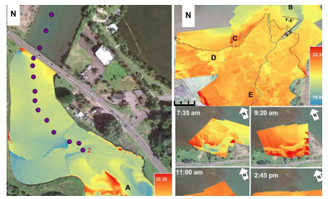
PHOTO BY TIM BRIGGS

### Isabel Gutowski, Marine Biology, 2018

Isabel took advantage of Northeastern's unique Marine Science Center in Nahant to partake in an REU within the Ries lab this past May and June. Collaborating on a joint experiment between the Ries and Lotterhos labs, Isabel helped investigate the effects of acidification and temperature increases on oyster populations in captivity. The oysters' tissues were later sampled and analyzed in a genetic lab to study oyster epigenetic responses to the stressful environments
of ocean acidification. In addition, Isabel sampled and tested the pallial fluid from within the oyster, measuring their pH levels based on speculation that pallial fluid changes help them cope with environmental changes.

On a day-to- day basis, Isabel weighed oysters, monitored water quality and food abundance, and assisted in tissue sampling. On occasion, Isabel also collected oysters for sampling from the nearby salt marshes. Today, Isabel continues her work at the MSC by participating in its outreach program as part of her co-op, educating people and spreading awareness of our ocean and the issues it faces today.

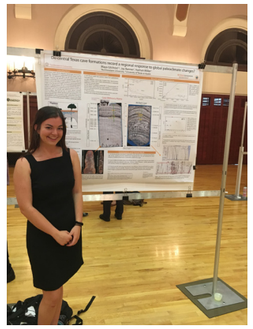
### Dan Litchmore, Geology and Chemistry, 2019




Out of 600 students, Dan was one of ten selected to participate in an REU at the University of Hawaii at Manoa. Dan's team studied volcanic outlet discharge behavior, and he specifically contributed by flying drones across volcanoes to observe temperature differences from within plumes and surrounding bodies of water. This helped to ascertain how to pinpoint pollutant discharge given the dilution of debris in a plume. In addition, Dan was able to spend time on a research vessel and collect rock samples from four kilometers under the ocean surface.

He also explored the island of Oahu collecting isotopic water samples from rainwater in watersheds, and biked Volcano National Park to observe active lava flows. Dan designed his phone case to feature the image of one such lava flow he observed! Dan will present his findings at the American Geophysical Union Conference in New Orleans this December.

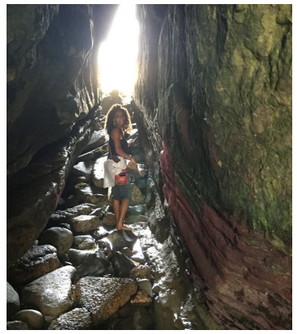
### Maya Gilchrist, Environmental Science, 2017



Did you know caves are one of the two places on Earth veiled in total darkness? (The deep ocean is the other.) Maya found this out in her time at the Environmental Science Institute of University of Texas, Austin, as she explored caves all over central Texas. Her lab group in the Climate Change in Semi-Arid Regions REU investigated climate signals in karst systems - soluble rocks such as limestone, dolomite and gypsum typically found in caves. By investigating speleothems, or calcitic cave formations, information on climate changes from moisture and precipitation levels can be extrapolated to better understand climate change. Maya's project involved comparing speleothems from differing caves to predict regional climate change across the ages, specializing in the time period between the last glacial period and the Holocene epoch, around 12,000 years ago. In addition, Maya participated in helping sample for an ongoing cave monitor.

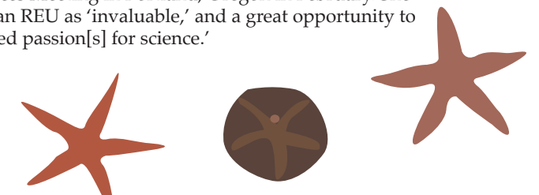
The majority of Maya's REU took place in a lab, analyzing rare metal data and microscopy sampling. She also took dripwater samples and measured air parameters from the caves she explored. Reflecting upon her experience, Maya noted that her fieldwork in caves was 'humbling' and gave her the chance to explore the 'scientifically unique and beautiful' nature of the caverns that are typically closed off.

### Jaxine Wolfe, Biology, 2019



A fourth-year biology major with a love for all things marine science, Jaxine has kept busy by slotting into the Scripps Undergraduate Research Fellowship (SURF) in San Diego between stints at Northeastern's Three Seas program. Under the mentorship of Dr. Lisa Levin and her PhD student Natalya Gallo, Jaxine researched the structure of a demersal fish community within an oxygen limiting zone in the Southern California Bight. To better study this community, Jaxine participated in ocean trawls and dissected the catch to prepare them for isotopic sampling; she then used the statistical program R to process the results of these samples and model community trophic interactions.

In addition to her research opportunities, the SURF program also facilitated research talks, student symposiums and educational trips and outings, while giving her time to explore San Diego, surf and socialize. Jaxine will present her work from the SURF program at the upcoming Ocean Sciences Meeting in Portland, Oregon in February. She endorses the value of participating in an REU as 'invaluable,' and a great opportunity to 'meet inspiring people with like-minded passion[s] for science.'



# I ♥ Co-op: A look into the first on-campus science communication co-op

BY SAGE WESENBERG, BIOLOGY AND JOURNALISM, 2019

DESIGN BY KRISTI BUI, COMPUTER SCIENCE, 2021

**I want to be a science writer** because I want to make science interesting, describing it in a way that anyone could understand and be curious to know more. Science communication is such an essential part of our lives these days, as everything we do or observe relies on an understanding of medicine, technology, the environment, or another area of scientific research. As I pursued a second co-op for this fall, I looked for jobs that would intertwine my interest in science with my interests in journalism and communication in order to make science interesting and accessible to others.

Since middle school, I have enjoyed writing about science, from lab reports to projects on baking bread. Coming to Northeastern, it was difficult for me to separate my interests and I was lucky enough to find the perfect outlet in NU Sci. I knew that as a biochemistry major with a goal of becoming a science journalist, I was unique in my class of future doctors and researchers. Completing my first co-op as a research assistant in an epigenetics lab at Harvard Medical School/Boston Children's Hospital helped me become even more certain that I was meant for a path that involved writing of some sort, away from the lab bench.

During my third year as a writer for NU Sci, I had the chance to connect with Lori Lennon, the Director of Communications for Northeastern's College of Science. With Lori's encouragement, I became a freelance writer for the college and wrote articles about new milestones and discoveries by students and faculty. As a past journalist herself and a Northeastern alumna, Lori was excited by the prospect of creating a co-op with me to work in the Marketing and Communications Department for the College of Science. Through the spring, she worked to help shape a job that would allow for many opportunities in science journalism and communication.

As I began working in July, I was welcomed by the many friendly staff and faculty working in the Dean's Office and Marketing and Communications Department for the college. Right off the bat I was setting up interviews with professors, assisting on projects for various co-workers, and learning about how the College of Science works from a totally new perspective. I quickly became swept up in busy weeks of article writing, meetings, and birthday celebration bagels. I soon found my rhythm as a valued part of the marketing and communications team, and began to grow more confident in making connections and taking the lead on assignments.

In the first three months of my co-op, I have written and published over 25 articles on topics ranging from a nanophysicist's approach to sequencing DNA to invasive species to the connections between eye movement behavior and neurobiological problems. I have had the opportunity to interview and work closely with many of the amazing faculty in the College of Science and learn about their research. I've also been able to lend a hand on other projects in the COS office, from creating infographics and brochures, to learning about marketing and social media initiatives, to assisting in a college-wide web redevelopment project.

> "Some of my stories have taken me well outside my comfort zone, as I've covered everything from particle physics at The European Organization for Nuclear Research (CERN) to algebraic geometry."

It's been amazing to meet so many people across campus, some of whom work in fields that I would never have come across in my classes. For example, Dr. Meni Wanunu, professor and biological physicist in the Department of Physics, showed me the tools that can create synthetic nanopores to observe the structure and function of molecules like DNA and proteins. Another highlight of my experience was meeting with Dr. Adam Hall of the Barnett Institute for Chemical and Biological Analysis and learning about his new research project on the opioid epidemic in Massachusetts. Hall is studying the metabolites of adulterants - chemicals that change the potency of drugs like heroin - to create a map of Massachusetts that shows where different types of heroin impurities are coming from in order to better prevent overdoses. Some of my stories have taken me well outside of my comfort zone, as I've covered everything from particle physics at The European Organization for Nuclear Research (CERN) to algebraic geometry. All of these experiences have introduced me to new areas of research and innovation in the College of Science and have also helped me hone my writing skills. I hope that by reading the articles I have written while on co-op, students and faculty from at Northeastern can gain insight into the amazing research that goes on in the College of Science.



# Dr. James Monaghan dives into the research pool of aquatic animal models

BY SPURTI VEMURI, BEHAVORIAL NEUROSCIENCE, 2021

DESIGN BY KRISTI BUI, COMPUTER SCIENCE, 2021

**Although when one thinks of** scientific research with animal models one usually thinks of mice or rats, a large branch of animal research involves aquatic animals. More specifically, aquatic vertebrates are good representatives for human disease because, just like you and me, they have a spinal cord and vertebrae. In addition to the physical similarities, most of the genetic makeup of aquatic animals is like that of humans. This allows researchers to manipulate an aquatic vertebrates' genes and observe how these mutations physically manifest themselves. Another benefit is that aquatic vertebrates not only have physical similarities to humans, but they allow researchers to visualize these similarities through development. Instead of growing in the womb like a terrestrial vertebrate would, aquatic vertebrates lay eggs and therefore develop externally. So, although mice have been dominating the labs as the most common models of human disease, aquatic vertebrates provide much more insight into the physical properties of diseases and mutations that mice cannot. For example, if a researcher is studying a developmental defect, it is helpful to be able to see what is happening at every stage. Some of the most common aquatic animals used as models for human disease are Zebra fish (Danio rerio), African clawed frog (Xenopus laevis), and the Mexican axolotl salamander (Ambystoma mexicanum).
Dr. James Monaghan is a faculty member of Northeastern University and studies Regeneration Biology. With the help of post-docs, graduate students, and undergraduate volunteers, the Monaghan Lab utilizes the amazing regenerative capability of Ambystoma mexicanum, also known as the axolotl, to investigate the properties of tissue regeneration in humans. In order to conduct these investigations, the axolotls are bred within the lab and monitored throughout development. The research assistants that work at the lab are responsible for axolotl care, cleaning the tanks, monitoring water quality, and running experiments. The laboratory that hosts these salamanders is equipped with state of the art water filtration systems that regulate temperature, pH, and salt.

> "Imagine if senior citizens had the ability to grow back an arm while still looking like teenagers!"

The axolotl is a unique species of salamander that can lay anywhere from 300 to 900 eggs which mature in the span of a year. This cost-efficient reproductive capability and their genetic similarity to humans make them good subjects. Axolotls are also reliable specimen to breed in captivity and do not need to be collected from a pond, unlike other salamander species. Furthermore, a genetic mutation that causes axolotls to remain at the tadpole stage of metamorphosis throughout adulthood sets them apart from other salamanders. Being able to understand the "metamorphic control" axolotls possess may help unravel the mystery of aging and the processes that regulate maturation in humans. An axolotl possesses the amazing ability to regenerate its limbs, tail, parts of the brain, and even the spinal cord. The fact that it can do so while remaining in a juvenile stage of development makes them unique. Imagine if senior citizens had the ability to grow back an arm while still looking like teenagers!

The Monaghan Lab researches the underlying cellular and molecular properties of regeneration in the salamanders and how they relate to humans by conducting experiments that explore gene expression patterns of the Mexican axolotl. Once the gene candidates are identified, the lab is able to conduct more specific experiments such as skin regeneration for scar-free healing in vertebrates, nerve dependent limb generation, and ovary regeneration. The ability to raise and study axolotls in an environmentally controlled system allows for the exploration of a broad range of biological concepts like regeneration, human infertility, aging, and gene expression.

When Monaghan first joined the field in 2003, there were only about one hundred genes available in the entire human genome. After the DNA sequencing explosion, many researchers studying genomics had access to the entire genome and had a stronger foundation to perform research. Earlier, they were only able to pinpoint where a gene is turned on and off. But according to Monaghan, gene knockouts are the next frontier for genetics research. Just as the boom in DNA sequencing allowed many opportunities to perform research in the field of regenerative biology, the new ability to edit the genome will have the same effect on new research techniques over the next decade. As our knowledge of genomics and biology continues to advance, the pool of research utilizing aquatic animals as models will only continue to expand.

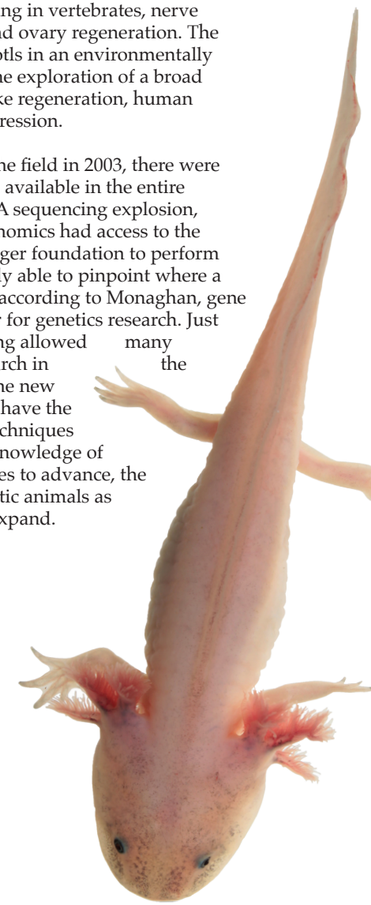


PHOTO BY KAZAKOV MAKSIM

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