JOLT MAGAZINE

Haverford's student-led STEM publication

SPECIAL ISSUE

SPECIAL ISSUE:
WEB ARCHIVE
2021 – 2023

EDITORS' NOTE

Dear Reader,

It's hard to believe that *Jolt* started as a casual chat between two bored students during a chaotic, pandemic-ridden freshman year. We noticed a void in science journalism on campus, and so we got to work trying to fill it.

Since our founding, *Jolt* has strived to bring you engaging and accessible science content, producing both online content and a semesterly printed issue. Now, we're ready to move in a new direction. I'm writing this note to document a change in our publication format. We've decided to decommission our website so we can direct our energy toward creating a high-quality semesterly print magazine. Thus we hope to deliver a richer, more curated collection of articles and stories.

I'd like to take this opportunity to thank our founding editorial board members, Anubhav Sharma '23, August Muller '23, Charlotte Park '22, Griffin Kaulbach '21, Lucy Zhao '22, Lydia Guertin '24, Sam Tan '23, Trea St. Hillaire '23, Catherine Kim '23; and our faculty advisors Dr. Joshua Sabloff and Dr. Karen Masters. Their creativity, commitment, and engagement were instrumental in laying the groundwork for the magazine.

I especially want to thank my co-founder Anagha Aneesh '24. Building Haverford's first student-led science magazine from scratch as freshman without any prior experience was a challenge that I am grateful to have undertaken with her. Anagha, your vision, hard work, and late-night brainstorming sessions are still the spirit of *Jolt*.

This special issue is a tribute to these and many other online contributors since *Jolt*'s founding in 2021. We've compiled all previous web articles to fully embody and celebrate the fantastic work our contributors have done over the years.

Our commitment to accessible science communication remains — a digital version of our print publication will be available on the Haverford KINSC website so that you can access *Jolt* from anywhere.

Thank you for reading and supporting *Jolt*! We hope you enjoy this special issue.

Warm Regards,

Emi Krishnamurthy '24, Co-Founder

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Webb NIRCam composite image of Jupiter from three filters – F360M (red), F212N (yellow-green), and F150W2 (cyan) – and alignment due to the planet's rotation. Credit: NASA, ESA, CSA, Jupiter ERS Team; image processing by Judy Schmidt.

April 11, 2021

SPRING SKIES: MARTIAN FEVER

Written by Karen Masters, Professor of Astronomy and Physics at Haverford College

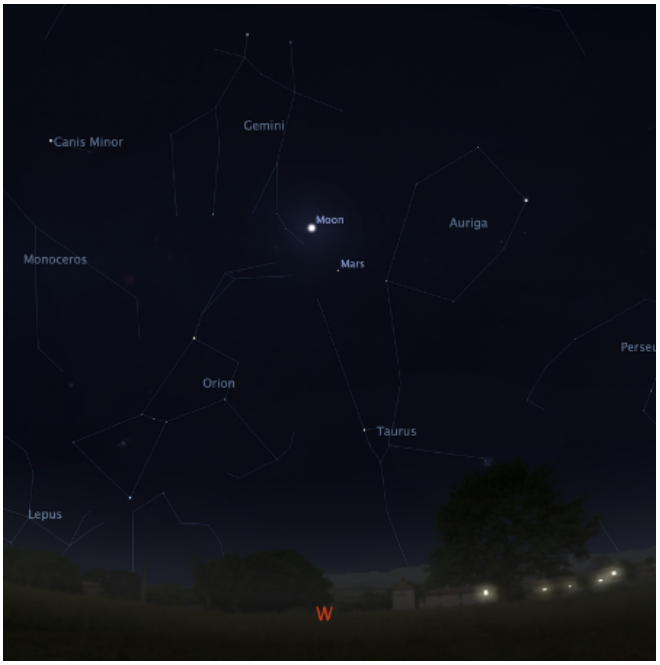
Edited by Lydia Guertin and Nora Reidy

If you plan to go stargazing just once this spring, you should find the planet Mars. You cannot have missed how missions to Mars have been in the news recently, with three missions arriving at the planet in mid-February. The orbits of Mars and Earth line up every two years, creating a window of favorable conditions to send spacecrafts. During the last window which opened in July 2020, three separate spacecraft were launched: the "Hope" spacecraft from the United Arab Emirates (UAE), China's Tianwen-1 spacecraft, and a mission from NASA which includes both a robotic rover "Perseverance" and a helicopter called "Ingenuity." That's right, a helicopter is (hopefully) going to fly on another planet, and this spring you can see Mars in the evening sky while it's there.

To find Mars, look for a reddish orange point of light in the west after sunset; if you are on campus, stand on the far side of the Observatory with your back to the building. Over the course of the spring, Mars will pass in front of two of the most easily identifiable Zodiac constellations—Taurus and Gemini—which you might also enjoy finding. It will spend some time close to the beautiful star cluster known as the Pleiades (or the Seven Sisters), which you can use to do the traditional eye sight test (how many sisters can you see?); finishing up the view will be the iconic Orion constellation to the left.

The included screenshot from Stellarium.org, a free planetarium software, shows the view at 9.00pm on Saturday April 17th, when the crescent Moon will be close on the sky to Mars, but any evening this semester will work just fine to see all of this.

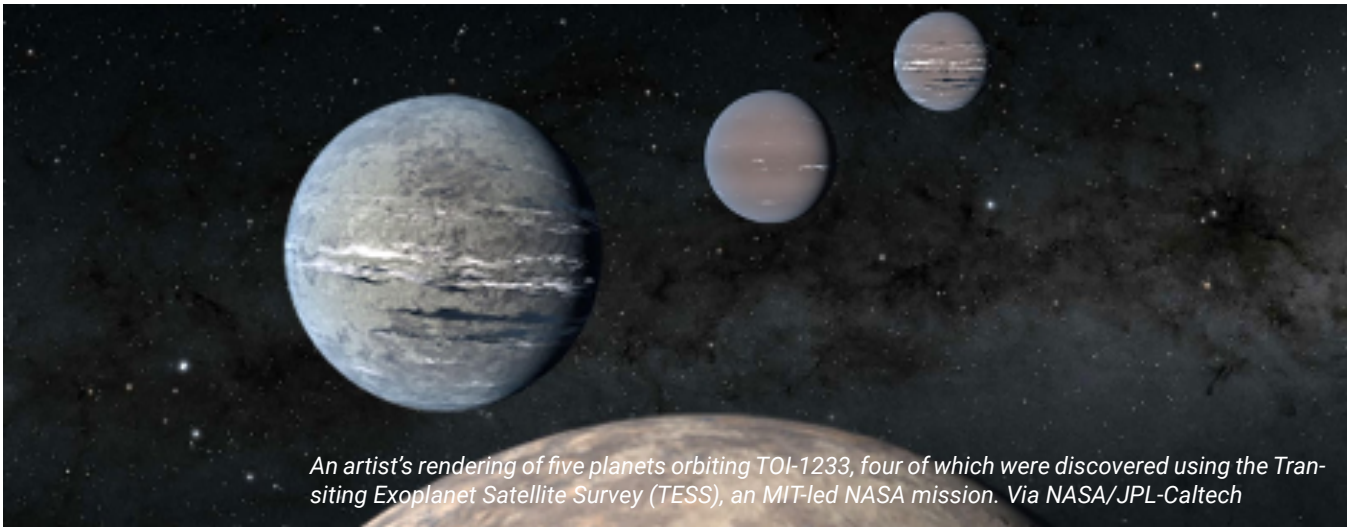
The spring can be a challenging time for stargazing, as it's not yet warming up and the hours of darkness are shortening. Marking this change of the seasons is the Spring Equinox, when the hours of daylight equal those of nighttime all over the world. This year, the equinox will happen early in the morning of March 20th; the exact date varies around March 21st because of leap days and the slightly elliptical shape of the Earth's orbit around the Sun. This changing length of daylight is why we change our clocks in the spring, moving them forward one hour on a Sunday (this year Sunday March 14th). The downside is having to get up an hour earlier to make our classes on time, but the benefit (unless you want to see the stars) is extended daylight hours in the evenings.



A screenshot of the night skies above the Western horizon at 9.00pm on Saturday April 17th. Via Stellarium.org (free planetarium software).

However, the spring also reminds us of the many different cultural connections to astronomy, particularly the Moon. The Lunar New Year is always celebrated on a New Moon in January or February; this year it was February 12th. Later in the spring, the Christian festival of Easter is also set by the lunar cycle: the festival happens on the first Sunday following the first Full Moon after the Spring Equinox, falling this year on April 4th. For Muslims, the dates of Ramadan are also set by the Moon. Observance begins with the first crescent Moon sighting in the evening after the April 11th New Moon, and the end is marked by the crescent Moon sighting after the May 11th New Moon. If you want to see the Full Moon this semester, look out for it in the west in evenings around the end of the month (February 27th, March 28th, or April and May 26th). A personal favourite of mine is the "morning Moon," the time around the first quarter phase when the crescent Moon is visible to the east in the morning. Try looking for this around February 19th, March 21st, April 20th or May 19th.

Happy Stargazing, and keep looking up.



An artist's rendering of five planets orbiting TOI-1233, four of which were discovered using the Transiting Exoplanet Satellite Survey (TESS), an MIT-led NASA mission. Via NASA/JPL-Caltech

April 11, 2021

FOUR NEW EXOPLANETS DISCOVERED

Written by Hannah James

Edited by Lydia Guertin and Luka Austin

The discovery of four new exoplanets gives insight into how scientists search for habitable or previously inhabited exoplanets.

Exoplanets are just like the planets in our very own solar system, but with one key difference: They orbit around other stars instead of the Sun. Because exoplanets orbit bright stars, they are very difficult to detect with telescopes, so the discovery of an exoplanet is a very big deal.

MIT researchers recently discovered four new exoplanets. Tansu Daylan, a postdoc at the MIT Kavli Institute for Astrophysics and Space Research, published the discovery in The Astronomical Journal on January 25, 2021. The four new exoplanets were found 200 light-years away, orbiting a sun-like-star called TOI-1233 (one light-year is the same as 6 trillion miles, or 9 trillion kilometers).

One exoplanet was already known to orbit TOI-1233. The four new exoplanets were discovered using the transit method, in which astronomers look for a change in the amount of light that is coming from a star. A small momentary decrease in the amount of light coming from a star could indicate that a planet passed in front of it.

Studying the properties of this light can tell researchers a lot about the planet passing in front of the star. It can reveal the size of the planet, the length of the planet's orbit, and whether there are other planets orbiting the same star.

The transit method can be combined with other investigative scientific methods to discover more about the exoplanet. Using the transit method while also measuring the planet's gravitational effects on its star can tell researchers whether a planet is rocky or gaseous, hot or cold, and whether it has a thick or thin atmosphere.

The four new exoplanets were detected using the Transiting Exoplanet Survey Satellite (TESS). Using data from TESS, as well as data collected from ground-based telescopes, Daylan and his team were able to categorize the planets. One of the exoplanets is large and rocky, known as a super-Earth. The other three are outer planets and are gaseous. These gaseous planets are a bit smaller than Neptune, and are known as sub-Neptunes.

Multi-planetary systems like this one give insight into planet formation and evolution, especially because the planets orbiting the star are so different.

To analyze the four new exoplanets' atmospheres and determine their molecular content, scientists will use atmospheric characterization with NASA's James Webb Space Telescope (JSWT). JSWT is an orbiting infrared observatory that will complement the Hubble Space Telescope. The JSWT has longer wavelength coverage and is more sensitive than the Hubble Space Telescope, which makes it better at looking into dust clouds, which are where stars and planetary systems form.

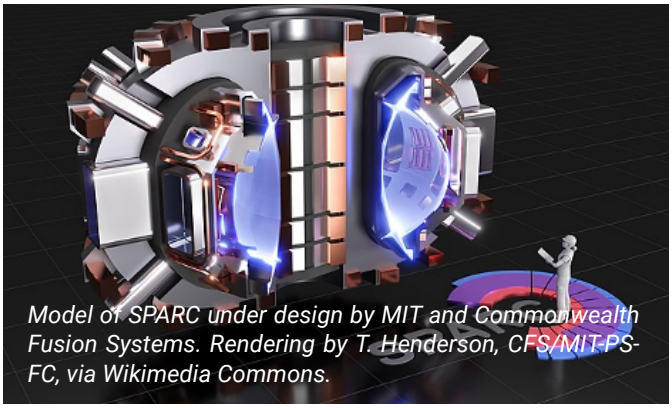
Collecting data from exoplanets provides the key to understanding and investigating the diversity of planets in the universe. It also gives insight into the formation of planets. Furthermore, investigating exoplanets' atmospheric properties contributes to the search and identification of habitable or already inhabited exoplanets.

April 11, 2021

A NEW "SPARC" OF HOPE FOR FUSION ENERGY

Written by Celeste Cubbage

Edited by Ellen Carlson and Anagha Aneesh



Model of SPARC under design by MIT and Commonwealth Fusion Systems. Rendering by T. Henderson, CFS/MIT-PSFC, via Wikimedia Commons.

A new spark of hope has recently emerged in the field of clean energy technology: the SPARC fusion reactor. Scientists and technicians affiliated with the U.S. Department of Energy (DOE) and the Massachusetts Institute of Technology (MIT) have been collaborating on this new fusion energy reactor, which has more promising projections than previous reactors.

Fusion energy provides a carbon-free, abundant power source that is safer than nuclear power with virtually no long-life radioactive waste. Matter becomes plasma by being heated in large cavities to temperatures hotter than the center of the sun. This plasma is then put under pressure to force nuclei collisions that lead to fusion reactions and the subsequent release of energy. This same process occurs in stars, like our sun, to keep them burning.

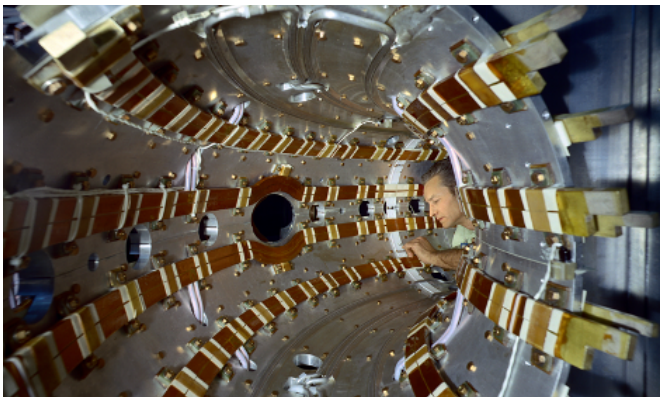
Most experimental fusion technologies use tokamaks, large machines with doughnut-shaped cavities, to hold and rotate plasma for fusion reactions. However, as noted by the 2021 FAQ page for the MIT Plasma Science and Fusion Center, no one has yet designed a reactor that produces more energy than required to trigger the fusion reaction.

A collaboration between researchers at Princeton Plasma Physics Laboratory, a DOE National Lab, and Commonwealth Fusion Systems, a startup born at MIT, hopes to solve this problem. The team has developed a fusion reactor with a tokamak-like design that utilizes newly available superconducting magnets. In theory laid out by the SPARC design brochure, the extra strong magnetic fields created by the superconducting magnets could provide the perfect insulation to confine the plasma within the reactor and avoid energy leakage. The extra strength of the magnetic field would also allow the reactor itself to work on a smaller scale than previous tokamak designs, making the reactor faster and cheaper to produce.

Even so, developing the SPARC model is only the first step. Once the physical structure is successful, the team plans to begin work on creating and operating a fusion plant with large-scale energy production. Currently, only outlines are available, but scientists hope to achieve designs for plants that can produce as much as the International Thermonuclear Experimental Reactor (ITER) — the world's largest tokamak fusion reactor, currently under construction in France — at only a fraction of the size.

Oscar Schwarts states in an interview from December last year that scientists hope to prove fusion is capable of becoming an economically competitive renewable energy source. This portion of the project would mainly be commercial with some input or aid from MIT and the U.S. Government.

As of now, the timeline projects that a plant could be operating and producing energy for the grid in a little as 15 years, with the goal of 2033. This goal, while possibly seeming far off, would actually be far faster than any existing fusion power initiative. If this proves possible, fusion energy could even encourage energy companies such as utilities or oil gas companies to finally pivot to carbon-free energy, because around-the-clock fusion reactors would be more reliable than intermittent wind and solar power generation. Fusion energy may prove to be a key factor in the universal switch to carbon-free energy.



Inside the Oak Ridge Tokamak in Tennessee. Photo by the Oak Ridge National Laboratory, CC BY 2.0, via Wikimedia Commons.

April 11, 2021

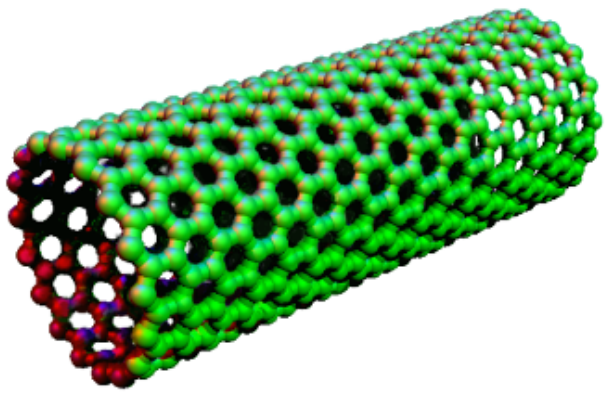
YOU'VE GOT MAIL, AND IT'S FROM SPINACH

Written by Catherine Kim

Edited by Sarah McNamara and Hedy Goodman

The idea of plant-to-human communication may seem far-fetched, but not for a certain team of chemical engineers. With the power of nanobionics, Dr. Michael Strano's chemical engineering lab at MIT implemented a process in which the ordinary spinach plant can detect toxic nitroaromatic compounds found in explosives and relay such detections wirelessly — in the form of an email.

Plant nanobionics, according to Dr. Strano, aims to "introduce [structures] into the plant to give it non-native functions." Strano's lab previously created carbon nanotubes — cylindrical molecules made of rolled-up sheets of single-layer carbon atoms — able to sense a variety of compounds, ranging from hydrogen peroxide to TNT. He makes use of these nanotubes in a 2016 study in Nature Materials where he explores the potential for plants to monitor the environment. "Plants are very good analytical chemists," he says. "They have an extensive root network in the soil, are constantly sampling groundwater, and have a way to self-power the transport of that water up into the leaves."



Model of a carbon nanotube, which is inserted into spinach leaves to detect chemical compounds. Image by Jorge Stolfi, via Wikimedia Commons.

In order for the team to locate such organic compounds in the soil, they inserted carbon nanotubes that release a fluorescent signal — either once when a volatile compound is found or continuously as a reference — into spinach leaves. When the spinach plant's roots draw in potentially explosive compounds from groundwater, they are detected by the leaves roughly ten minutes later, allowing the nanotubes to elicit a signal. An external infrared camera connected to a $35 Raspberry Pi computer then captures these signals, automatically alerting the scientists via email. An alternative could even be a smartphone camera (with its infrared filter removed), illustrating the study's low equipment cost.

Today, Strano's team is still hard at work to discover more applications of their spinach nanotube experiment. While their original 2016 study focused on the detection of explosive compounds useful for surveying landmine zones, the plants can be adjusted to detect compounds associated with pollution and climate change in the soil. Not to mention, the team engineered spinach plants that detect dopamine, which affects plant growth, and are also working on developing plant hormone sensors and increasing the distance from which signals are received, which is currently only about a meter away.

In this manner, Dr. Michael Strano and his team exemplify the surprising potential of using plants as nature's sensors: they aid in the detection of rare compounds, reveal aspects of internal plant processes and plant health, and provide warnings of ecological change, all in real-time. This project demonstrates the future of the budding field of plant nanobionics and is a stepping stone toward scientific advancements in environmental analysis.

April 13, 2021

HARNESSING PLANTS' CARBON STORAGE FOR A GREENER FUTURE

Written by Griffin Kaulbach

Edited by Emi Krishnamurthy and Catherine Kim

In sunny La Jolla, California, the founders of the Harnessing Plants Initiative (HPI) at the Salk Institute are thinking about the big question that connects agriculture, wetland restoration, and atmospheric climate change: How can we safely use plant pathways to capture and store carbon, while restoring our agricultural and coastal environments?

According to Joanne Chory, leading Lebanese American plant biologist and co-director of HPI, "If we can optimize plants' natural ability to capture and store carbon, we can develop plants that not only have the potential to reduce carbon dioxide in the atmosphere but that can also help enrich soils and increase crop yields."

How can we do that? The answer lies in a biomolecule called suberin, which is present in the cell walls of corky tissues of plant roots and stems. When suberin associates with cork, it becomes a tool for storing carbon. Scientists at the Salk Institute study the molecular tags that control whether suberin genes get turned on or off, as well as upregulation methods. However, for development of edible and reliable crops, it is unwise to just overexpress the genes to create high concentration of suberin. Plants also need to be bred to grow more extensive and deeper root systems to create a larger surface area for storing suberin.

Thankfully, deep plant roots are already a favored trait, especially in response to climate change because they increase plant stress resistance to drought, flooding, and disease. More extensive root systems are also beneficial for soil health because they attract soil microbiota and fauna and replenish the soil with organic carbon.

In 2019, the lab of Wolfgang Busch, the other co-director of HPI, identified a gene that helps regulate root system architecture. Manipulating this gene's expression, in addition to that of the suberin genes, can lead to the development of "super plants" that have deep root systems and are good at storing carbon.

There is one more issue to solve: how can we make these super plants live longer? The Chory and Busch labs are in the midst of answering this question, testing ways to make the larger roots last longer and resist decomposition. Additionally, the greenhouses at the Salk Institute are filled with scientists using x-rays, machine learning, and many other tools to measure suberin content, root growth, and carbon storage at all stages of plant development.

Enhanced root growth of 5 or 6 economically important crops worldwide could devote 768 million hectares of land to carbon capture, and the only additional step would be for farmers to rotate in a new line of seeds.

HPI started studying roots with Arabidopsis thaliana and Lotus japonicus as their model species, and this year, they began their first experiments on more widely grown crops, like soy, rice, wheat and canola. Additionally, HPI is "developing wetland plants that hold carbon, purify water, preserve land and can thrive in challenging environments around the world," since wetlands can store as much as 100 times more carbon per acre than dry land, but are rapidly eroding and emitting carbon into the atmosphere.

Counter arguments against this work concern the ethics of GMOs and the efficacy of carbon capture. Busch provides reassurance: the study is a safe and efficient effort towards the climate change solution, and we need to "reduce the amount of carbon dioxide in the atmosphere through many different means."

The HPI report includes introducing these super plants into our wetlands and agricultural lands as one part of a larger land regeneration proposal, as well as emitting less carbon dioxide into the atmosphere. The focus of this work is bringing us closer to achieving consistent crop yields and ensuring food security for a growing global population.

Wheat, canola, soybean (pictured here) and rice are effective candidates for carbon capture because they grow quickly. Soybeans coming up in a rye cover crop May 2016. Photo by USDA NRCS South Dakota, via Wikimedia Commons.

April 13, 2021

HALTING MISINFORMATION IS CRUCIAL IN BATTLING CONSPIRACIES

Written by Lukas Voelkner

Edited by Rebecca Stevens and Emi Krishnamurthy

At a QAnon rally in Los Angeles (2020). Photo by Joel Muniz via Wikimedia Commons.

Was the moon landing faked? Is the Earth flat? Does Bill Gates inject microchips in Americans? (The answer to all of these is no.) There are many popular conspiracy theories held amongst the American population. With very little to no evidence backing up conspiracies, why do so many people believe in them? A recent study from the Philipps-University emphasizes the importance of limiting the spread of misinformation.

A conspiracy theory is a belief that some covert but influential organization is responsible for a circumstance or event. Conspiracy theories and the spread of misinformation are increasingly prevalent problems in American society. According to a 2014 study published in the American Journal of Political Science, 50% of Americans believe in at least one conspiracy theory. They have corrupted many facets of life, from political integrity to the validity of hard science. With the ease of accessing information, the threat of conspiracy theories is becoming an ever-pressing issue.

Stephanie Mehl, a professor at Philipps-University, in Marburg, Germany, published her findings last year in Psychology. She aimed to understand the cognitive functions behind belief in conspiracy theories by measuring jumping to conclusion bias within participants. As the name suggests, jumping to conclusion (JTC) bias describes the psychological phenomenon by which individuals draw conclusions from limited information. Mehl hypothesised that participants who showed high levels of JTC bias differ from participants who didn't with respect to the quantity of conspiracy theories they believed.

Participants were subject to two psychological tests that assessed their belief in conspiracy theories and their level of JTC bias. The first was a questionnaire listing 20 of the most popular conspiracy theories (for example, Was John F. Kennedy not shot by Lee Harvey Oswald alone?). Participants ranked their agreement with the conspiracy theory on a five-point scale, with 5 being "I fully agree." The mean approval rate of the total sample was 2.63/5 across all theories.

In the second test, Mehl tested for JTC bias by asking participants to make a judgement about a constructed scenario with limited information. Participants were shown photos of two ponds with different ratios of blue and orange fish—40 to 60 for condition A, and 60 to 40 for condition B. Participants were presented with a fisherman's "catch" and were asked to classify which condition, A or B, the fish came from.

Mehl found that participants who made quicker judgements believed in more conspiracy theories than those who asked to see the catch again or to see another catch before making their judgment. Mehl extrapolated that individuals are less likely to want more information about the "catches," and are therefore more likely to believe in conspiracies, because of a higher level of JTC bias.

Conspiracy theories are so dangerous because of their effect on an individual's trust in the framework of society. This mistrust often leads to acts of violence or the rejection of authority. For example, there is no empirical evidence to support that the 2020 election was rigged, yet many still believe it. Believers of conspiracy theories are internally compelled to fight the system and spread the misinformation. Although fish categorization does not reproduce this internal drive, Mehl's research points to crucial information about belief in conspiracies.

6-20% of Americans believe that the U.S. government faked the moon landing, no doubt because there is an abundance of misinformation about it. If individuals do not require adequate empirical evidence to make a judgment on a topic, then at what point should we limit the access to misleading information? In an interview this January, Dr. Karen Douglas, professor of social psychology at the University of Kent, said, "It's much easier for people to find this sort of information now than it ever has been before."

The plethora of misinformation is widespread, and the real science is buried underneath a mountain of conspiracy theories. As a result, the beliefs are validated and the lies are perpetuated. The only clear solution to this seemingly endless cycle is a restriction on the spread of false information.

April 15, 2021

NEW ANTI-BIOFOULING TECHNOLOGY "SLIPS" INTO ACTION

Written by Isabel Thornberry and Atira Glenn-Keough

Edited by Catherine Kim and Griffin Kaulbach

Biofouling is a process that occurs when microorganisms, such as bacteria, form communities and adhere to surfaces. These communities are called biofilms, and once established, they often spread rapidly and expand onto other surfaces. Biofouling can create many problems for the environment and man-made structures as it interferes with and accelerates the degradation of infrastructure, such as plumbing and shipping. For example, marine biofouling occurs when biofilm on a ship accumulates, followed by other surface marine organisms, like algae and barnacles, causing ships to use up to forty percent more fuel. This increased fuel usage leads to water pollution and other negative effects.

Dried algae and rusty metal on a boat ramp. Photo by W.carter, via Wikimedia Commons.

Because of the rapid nature of biofouling, it is important to find solutions that can prevent initial bacterial attachment and continuous spread of the microorganisms. However, previous solutions to biofouling have generally involved the application of harmful chemicals proven dangerous to a variety of ecosystems and human health. Thus, chemists have been looking to develop anti-biofouling technologies that are eco-friendly, help conserve energy, and reduce environmental hazards.

One way to prevent the accumulation of biofilms is by preventing the initial adhesion of microorganisms—scientists have been developing surfaces that do just this. Slippery liquid-infused porous surfaces, or SLIPSs, are composed of a silicone oil lubricant that fills nanoscopic honeycomb-like structures made of a polyester plastic. The porous surface design mimics the structure of tropical carnivorous plants, which similarly use a slippery liquid to trap prey. The textured surface of SLIPS makes the technology extremely durable because the lubricant better adheres to a porous surface than a non-porous one. In addition, SLIPSs are able to repel water, microorganisms, and other organic matter for extended periods. According to a 2012 study published in Applied Biological Sciences, over a week-long period, SLIPSs were proven to repel 96 to 99 percent of common bacterial biofilms.

Using sustainable technology such as SLIPSs diminishes the need to apply harsh, polluting chemicals and saves money by reducing the need for maintenance. Though SLIPSs and other anti-biofouling technologies are still being developed and tested, they appear to be relatively inexpensive, easy to manufacture, durable, and widely applicable, making them a viable long-term solution.

April 17, 2021

CREATING A REAL WARP DRIVE: ZERO TO 299,800,000 IN NO TIME

Written by Lydia Guertin

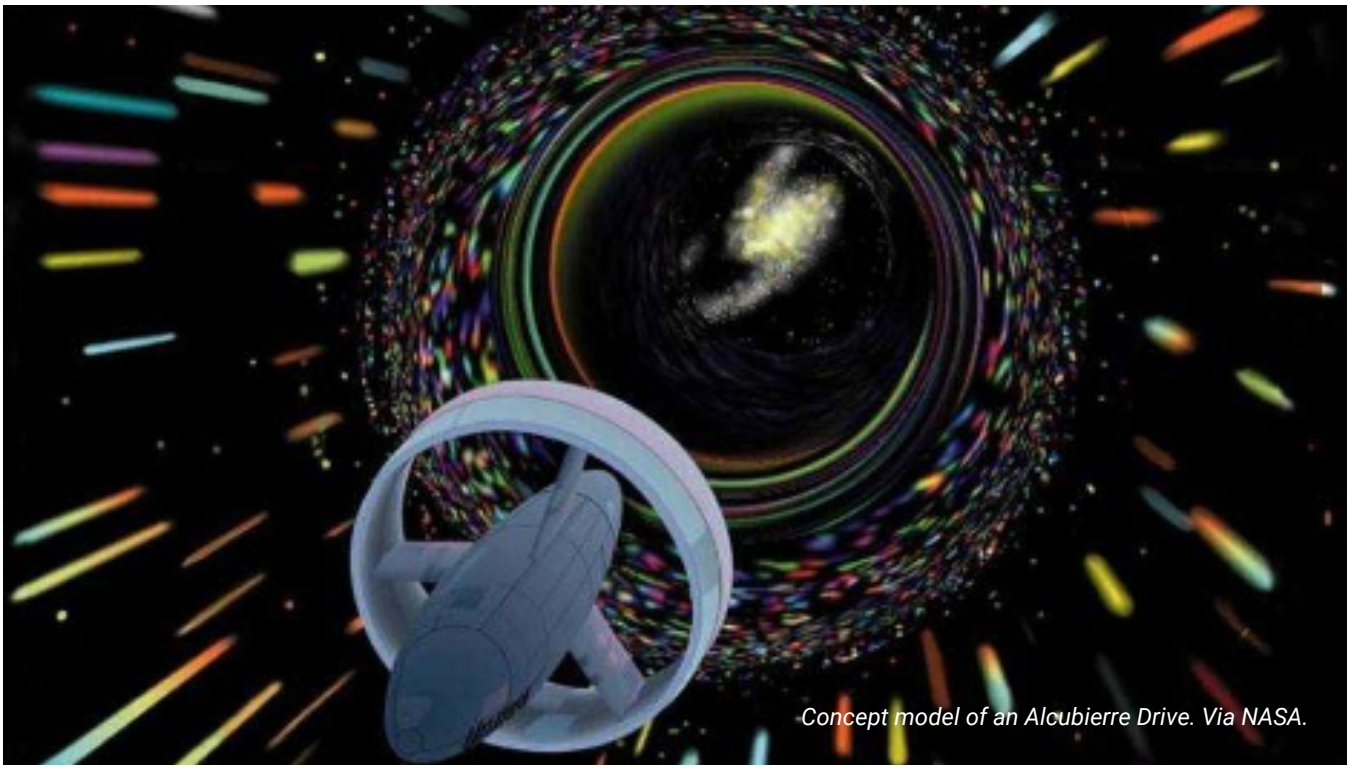
Edited by Sarah McNamara and Hedy Goodman

In 1994, Mexican physicist Miguel Alcubierre proposed something seemingly out of science-fiction: a real, working warp drive with the capacity to travel faster than the speed of light. Well, "working" in the theoretical sense, but even then it did not quite follow the ever-present laws of physics. A warp drive is a type of engine designed to travel at the speed of light, which is a revolutionary concept, if one can solve the issue of hurtling a spacecraft with much more mass than a photon through space.

This idea, while not practical when it was first proposed, sparked a movement in aeronautical engineering and theoretical physics, even catching the attention of NASA. On February 18, 2021, physicists Gianni Martire and Alexey Bobrick of the Applied Physics laboratory announced their model of an Alcubierre Drive that adhered to the laws of physics, making future distant space travel more plausible.

The issue with the original Alcubierre Drive regarded energy: how do you fuel something that is traveling at the speed of light? The answer: you don't. Instead of the "negative energy" model proposed by Alcubierre—in which enough energy would be generated to literally distort space around the ship—Martire and Bobrick propose using an incredibly large mass to warp the space around the ship, similar to how Earth warps surrounding space, resulting in gravity. The consequent "bubble" of space would then propel the ship forwards and, by effectively compressing the space the ship has to travel through, allow it to travel at very high speeds. Such a solution eliminates the need for "negative energy," and instead uses gravity as it works in our universe, as proposed by Einstein, to create a feasible warp drive.

While this proposal is exciting, the technology we currently have does not meet the level of sophistication required, and it is still unclear how we would get a mass so enormous onto such a small ship to create the bubble. Nevertheless, Martire and Bobrick's idea brings us closer to a reality previously viewed as entirely fantastical: cruising at the speed of light, a goal which is rich with possibilities for the advancement of astronomy and, more excitingly, establishing human contact



Concept model of an Alcubierre Drive. Via NASA.

April 19, 2021

SWIRLING PLASMA CLOUDS: WHAT WE KNOW ABOUT SPACE HURRICANES

Written by Lydia Guertin

Edited by Luka Austin and Hedy Goodman

Illustration based on recent confirmation of first-ever observed space hurricane. Qing-He Zhang/Shandong University

On August 20, 2014, researchers at Shandong University in China noticed some strange readings at Earth's polar regions. There were no solar flares, abnormal geomagnetic conditions, or other phenomena that could explain these readings, yet there was a storm building at the North Pole. This was no ordinary storm: massive plasma clouds with spiraling arms were beginning to take shape, pulling electrons in from Earth's magnetic field lines. While they didn't know it then, the team at Shandong University was watching the first observed "space hurricane." These space hurricanes aren't actually visible to our eyes, but we can observe them using ultraviolet telescopes, such as the SSUSI used to make these observations.

Earth's aurorae are caused by solar winds driving charged particles through space towards Earth, where some get swept up by Earth's magnetic field lines and swirl around them, ending up at the magnetic poles. This space hurricane has many similar properties to the aurorae seen regularly at Earth's poles, meaning it was likely generated the same way; however, given the relatively calm magnetic field and solar conditions on the day the space hurricane was observed, researchers still have many questions about what caused this huge particle storm above our North Pole. While it is true that there are always charged particles moving along our planet's magnetic field lines, the intensity of this storm and its magnitude seemed to suggest some other unknown phenomenon caused it.

An analogy between hurricanes seen on Earth and these new space hurricanes makes a lot of sense, Michael Lockwood explains in an interview with NPR: these dense clouds of charged particles throw electrons into our atmosphere the same way that hurricanes on Earth throw rain at us, resulting in weird effects on our satellites and GPS systems that we don't quite understand yet.

Discovering this new phenomenon has also opened up new questions about our planet's magnetosphere and weather in space, which leaves the team at Shandong University, as well as all of us, with just as many questions as answers. While we don't yet know what caused a massive plasma storm on what seemed to be a geomagnetically calm day, we do know that these charged particles likely interacted with our satellites in ways we can see, if we know where to look, and that we clearly don't know as much about space weather in the magnetosphere as we thought.

April 19, 2021

THE TWENTY-TWO PERCENT: A REVIEW OF GENDER IN PHYSICS

Written by Ashley Schefler

Edited by Emi Krishnamurthy

Note: This article will use some binary gender language ("women" and "men"). These were the genders studied and language used in the papers this article covers, but I acknowledge that this language does not encompass the whole spectrum of identities.

In February 2021, the Department of Physics and Astronomy at Texas A&M University published a study ten years in the making investigating the relationship between gender and performance in introductory physics courses. This article will review the results of the study, as well as the underlying problems that have led to the underrepresentation of women in the field.

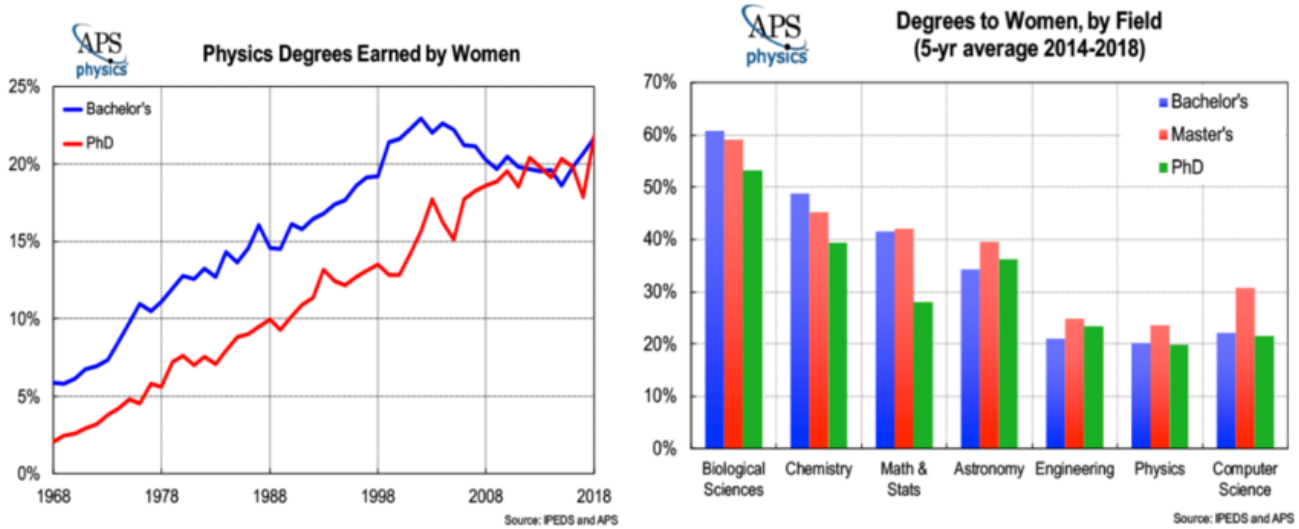
The Texas A&M study was notable in its scope, gathering data from over 10,000 students from 2007 to 2019 on not just final grades but also exam scores. The overall conclusion of the study was that there was no statistically significant correlation between gender and performance in these physics courses. However, there were a couple of interesting details that add nuance to that conclusion.

First, the only course that showed a statistically significant difference was the algebra-based mechanics course, typically taken by students pursuing majors outside of the physical sciences, in which female students performed slightly better than male students. Interestingly, this was also the course with the greatest percentage of female students (55.6%), while the other three courses studied had 55.4%, 25.1%, and 19.2% female students. Additionally, the study found several instances of women performing better in comparison to men (though only by a small amount) when the instructor was female.

The study also sent out a questionnaire, which asked whether the students felt included, how they thought they performed ("well below average," "below average," "average," etc.), and whether they felt their contributions were valued. For all the courses except algebra-based mechanics, male students rated their performance higher than female students, despite no difference in actual performance.

However, there was no statistically significant difference in feelings of inclusion or valued contributions (except in algebra-based mechanics). Women in these classes felt included and valued, but still had a distortedly negative perception of their performance; these feelings of inadequacy and self-doubt bring us to an important question: why was this study necessary?

Women are currently underrepresented in physics. In the United States, only 22% of physics bachelor's and Ph.D. degrees were earned by women as of 2018, a number that has made slow progress in the last 50 years, particularly when compared with other STEM fields (see figures below).



Graphs showing the underrepresentation of women in physics (2018). Image by IPEDS and APS.

Professor Lommen's research group at the International Pulsar Timing Array Meeting in Pune, India, 2019. Photo from Lommen's homepage with permission.

Why are women so underrepresented? In 2016, Physical Review Physics Education Research, published by the American Physical Society, did a special collection on Gender in Physics, which is a great resource for those interested in learning more about this topic and willing to parse through some scientific papers. As the Texas A&M study showed, women are not less capable at physics than men, and yet the gap in representation persists. Why? A 2016 paper by science education scholar Angela M. Kelly in this collection gives a particularly thorough review of the topic from a socio-psychological perspective. Using social cognitive career theory, which describes the psychology behind career choice and performance, this study explains factors that make women less likely to pursue physics education and careers, and interventions that will make the field more accessible to women.

On the psychological level, three key factors are self-concept and self-efficacy (psychological terms describing confidence in one's abilities), outcome expectations, and motivation. In other words, people are more likely to pursue a field if they are confident in their abilities, see a path towards success and satisfaction in that field, and have some intrinsic (coming from within) or extrinsic (coming from external influences and perceived outcomes) motivation.

Women often underestimate their physics ability, even if they are in fact performing just as well as men

Kelly's article discusses how these psychological phenomena contribute to women's choice to pursue or not pursue physics. Women often underestimate their physics ability, even if they are in fact performing just as well as men, as demonstrated by the Texas A&M study, among others. Stereotypes about boys being more suited to physics than girls can start as early as elementary and middle school, turning girls away from the field at a young age. A related issue is stereotype threat, in which anxiety about fulfilling a negative stereotype leads to worse performance. These stereotypes have at times been propagated by tests called concept inventory assessments, which are used in educational studies but may have demographic biases, as other studies have investigated. This is why the Texas A&M study, which used course performance instead and found results which negate this stereotype, is so important.

Additionally, classroom social environments are often hostile to women, who tend to prefer a supportive, collaborative atmosphere and often shy away from argumentative interactions and authoritarian teaching styles. Role models and familial

support can be incredibly influential in the decision to study physics, but the lack of female physics teachers and women in physics more generally means these role models are often absent. These factors combine to create a lack of self-efficacy and self-concept and low outcome expectations for women studying physics.

Kelly's paper also concluded that women tend to value intrinsic motivation, and are more likely to study physics if they see the applications and social relevance of the subject, something which is often underemphasized in physics curricula. This may be one reason biology and chemistry, which tend to emphasize medical and other applications, have been more successful in attracting women, as seen in the APS graph above.

It isn't all bad news. There are some promising and exciting interventions to increase the number of women in the field. Kelly's article emphasizes the importance of positive classroom environments which foster respectful collaboration, provide hands-on learning opportunities, and employ inclusive pedagogical strategies, such as asking about prior knowledge before beginning a topic and discussing student misconceptions. These classroom reforms have been shown to benefit both men and women.

There are some promising and exciting interventions to increase the number of women in the field.

Another strategy is to emphasize a malleable theory of intelligence, where ability is determined by hard work and improvement rather than a fixed level of talent, thus empowering women to overcome the stereotype-driven fear that they are innately less capable. Additionally, women would be more engaged by curricula which emphasize the social relevance and real-world applications of physics and strive for depth over breadth in topics covered. Teacher support and encouragement are also incredibly important; this can include having high expectations and giving critical feedback, which signal confidence and belief in students that they can improve and succeed. Women also need exposure to role models, particularly female role models, who enable them to envision their future in the physics field. Conferences and student groups geared specifically towards women in physics can help provide exposure to these role models and create a more supportive and welcoming environment.

Andrea Lommen, a member of the Haverford physics department, spoke about her experience as a woman in physics and some of the disparities she has seen. At one conference, she was one of roughly 5 women out of 25 physicists (a fairly standard ratio in the field) and one of the more senior members in the group. One of the other women came up to her and asked, "Do you ever feel like nobody's listening to you?" The woman was surprised to hear that Lommen felt this way all the time and was relieved to know that it wasn't just her, and that her ideas or her mode of expressing them weren't somehow inadequate.

Naval officer Gretchen S. Herbert speaks with young women participating in a Pre-College Experiences in Physics (PREP) Summer Program at the University of Rochester. Photo by U.S. Navy Mass Communication Specialist 1st Class Katrina Sartain, via Wikimedia Commons.

Some time later, a second and then a third woman asked Lommen the same question. Lommen assured them that not only had she felt that way herself, but other women at the conference had come up to her and asked her the same thing! Each person was shocked to hear that other women at the conference, who they perceived as so capable and well-spoken, had experienced this same apprehension. Afterward, Lommen noticed that the women not only felt more confident in themselves but started more actively speaking up for one another during discussions.

Lommen says she has frequently been in situations where a woman says something and is ignored, and then a few minutes later a man says the same thing and is commended. However, with increasing awareness of this type of (often unconscious) bias, she has also seen many wonderful examples of women and men alike stepping in when they see that anyone, including a woman, is being unfairly shut out of a conversation. Looking out for ways to be supportive and welcoming towards people of all identities is something that we can all do to help this issue, whether physicists or any other members of the Haver-

April 29, 2021

SCIENTISTS CLONE DISEASE-THREATENED FERRET SPECIES TO INTRODUCE GENETIC DIVERSITY

Written by Griffin Kaulbach

Edited by Rebecca Stevens and Ashley Schefler

Endangered black-footed ferret in an outdoor preconditioning pen at the National Black-footed Ferret Conservation Center in Colorado. Photo by Stewart Brand for the U.S. Fish and Wildlife Service.

For the conservation of endangered black-footed ferrets, scientists are going beyond protected areas and habitat restoration. Biotech companies and wildlife conservation organizations are working together to implement reproductive cloning to introduce genetic diversity into the disease-threatened ferret species. If successful, this method will create a more resilient population and show that reproductive cloning has the potential to save more of our vulnerable native species.

In 1988, a Wyoming rancher was surprised when his dog dropped the carcass of a black-footed ferret on the front porch because the ferret species was previously thought to be extinct. The native ferrets feed exclusively on prairie dogs as prey and used to hunt them in the grasslands of the American West, but when ranchers and farmers started to poison and exterminate the prairie dogs, numbers of the ferret species dwindled. The population of black-footed ferrets living on this Wyoming ranch were gathered for a captive breeding program because of the endangered status of the species, and now all living black-footed ferrets are genetic descendants of just seven closely related ferrets.

When you think of the conservation of endangered native species, has artificial cloning ever crossed your mind? It has been on the minds of those at Wyoming Game & Fish and the San Diego Zoo since the 1980s. Due to their foresight, there is a plan to possibly save the only ferret native to North America through artificial (or reproductive) cloning.

Meanwhile, Tom Thorne of Wyoming Game and Fish was observing and collecting black-footed ferrets in the state. He later sent tissue samples from frozen ferrets to Oliver Ryder, the director of conservation genetics at San Diego Zoo Global, to be kept at the "Frozen Zoo," thinking it might be useful at some point. In 1988, tissue samples from a black-footed ferret named Willa arrived at the zoo. The Frozen Zoo is a resource for conservation, assisted reproduction, evolutionary biology, and wildlife medicine and now boasts a collection of cryogenically frozen tissues representing 1,100 species. In addition to conservation efforts, whole-genome sequencing projects for African elephants, two-toed sloths, and gorillas have all benefited from the Frozen Zoo.

Hans Spemann, a German embryologist, set the stage for applying the use of artificial cloning of animals when he discovered embryonic induction, the process that directs the development of groups of cells into particular tissues and organs, in 1935. Many developments have been made since, including the successful birth and life of Dolly the Sheep, the first mammal to have been successfully cloned from an adult somatic cell.

In December 2020, Elizabeth Ann became the first-ever cloned endangered native species to be born in the United States. She was cloned using Willa's frozen cells collected and sent to San Diego's Frozen Zoo more than 30 years ago. Researchers inserted the nucleus from Willa's cells into an egg from which the nucleus has been removed. When the egg began to divide normally, it was transferred into the uterus of a domestic ferret, who birthed Elizabeth Ann. This is a process used in reproductive cloning, called somatic cell nuclear transfer.

Biotechnology nonprofit Revive & Restore and Viagen Pets, a company that clones pets, worked together on this project, culminating in the birth of Elizabeth Ann in late 2020. She lives in a Fish and Wildlife Service black-footed ferret breeding facility in Fort Collins, CO, and is closely monitored. Blood tests have confirmed her to be 100% black-footed ferret. She is the only black-footed ferret who isn't a genetic descendant of the 7 ferrets found on the ranch in the 80s.

Due to its small gene pool, the species is so threatened by disease that scientists inoculated 120 black-footed ferrets with experimental COVID-19 vaccines this summer. Black-footed ferrets currently have such similar genetics that one disease could wipe out the entire population. If additional cloning is successful and it is safe to introduce Elizabeth Ann into the genetic pool, she will bring much needed genetic diversity to a deeply inbred population. This exciting research has implications for future reproductive cloning and offers a last resort path for the conservation of other important endangered species.

April 29, 2021

THE OCEAN AS A KEY RESOURCE IN THE ANTIBIOTICS ARMS RACE

Written by Emi Krishnamurthy

Edited by Nora Reidy, Lucy Zhao, and Griffin Kaulbach

Shreya Kishore is currently a senior Chemistry major with a biochemistry concentration and health studies minor at Haverford College. As a peer tutor and member of the Chemistry Student Group, Kishore is passionate about increasing the transparency of Haverford's chemistry department. She plans on working toward her Chemistry PhD at Stanford University this fall.

One key solution to fighting antibiotic resistance is to discover new antibiotics. Shreya Kishore '21 shares how she screens marine bacterial cultures in pursuit of discovering a novel antibiotic.

Shreya Kishore '21 in the Whalen Lab at Haverford College.

Almost 100 years ago, Sir Alexander Fleming accidentally discovered a fungus, Penicillium notatum, growing in a petri dish of Staphylococcus bacteria he had accidentally left uncovered by an open window. Penicillins, the antibiotic chemicals produced by P. notatum, are now the most highly used class of antibiotics in the world. Since Fleming's discovery, antibiotics have saved millions of lives and transformed the field of medicine.

Antibiotics work by either killing bacteria or inhibiting bacterial cell growth and division. However, antibiotics also introduce an environmental pressure that allows resistant bacterial cells to survive, reproduce, and pass on this resistance. They can also transfer resistance to other bacterial cells, a process known as horizontal gene transfer. Increased administration of antibiotics exposes more bacteria to this environmental pressure, thus accelerating resistance-building to a given antibiotic.

After penicillin became widely available in the 1940s, the world entered a "Golden Age" of antibiotic discovery until the last class of antibiotics was discovered in 1987. This marked the start of a "Discovery Void" in which no new classes of antibiotics have been discovered and scientists have observed a marked drop in antibiotic discovery. Due to the lack of economic incentive, most pharmaceutical companies have stopped investing in antibiotic development in recent years. The effects of this Discovery Void worsen by the year as infectious bacteria become more exposed to — and thus increasingly resistant to — our current drugs.

The decline of new antibiotic discoveries and general overuse of antibiotics — through livestock feed, agriculture, and overprescription by doctors and healthcare providers — are simultaneously contributing to the problem. The CDC has repeatedly emphasized the severity of this trend, stating that "antibiotic resistance is one of the biggest public health challenges of our time."

Novel antibiotics can be developed from bacterial metabolites (natural metabolic byproducts) found in nature. In an environment with limited nutrients, bacteria produce antimicrobial compounds to kill or halt the growth of their microbial competitors. For decades, scientists have been looking to microbially rich sources such as soil, but more recently, researchers have started looking into marine natural products to harness the ocean's distinct and vast biodiversity.

Shreya Kishore '21 is currently examining marine natural products in order to discover a novel antibiotic. In the Whalen Lab, Kishore examines and grows marine bacterial culture samples, extracting each of its produced compounds. She searches for antimicrobial compounds within each culture that can be developed into antibiotics or act as efflux pump inhibitors.

Kishore explains that efflux pumps are located within bacterial membranes and pump antibiotics out of the cell. Since efflux pumps are non-specific — meaning that they can work on many different types of antibiotics — they are another way bacteria become multi-drug resistant. An efflux pump inhibitor (EPI) would block the function of efflux pumps, which can renew the effectiveness of an antibiotic for the bacteria. According to Kishore, finding either a novel antibiotic or an EPI "would have a broad clinical application."

In the lab, Kishore screened about 500 marine cultures and found about 20 to be active, meaning that they indicated effectiveness against pathogenic bacteria. Kishore's next step is to locate the exact compound within each culture that is responsible for the observed effect, and to find the mechanism by which these active compounds inhibit bacterial growth.

In addition to working toward discovering a novel antibiotic, Kishore and other researchers in the Whalen Lab are also screening a novel antibiotic identified in 2018 by Anna Schrecengost '18, who used similar methods to analyze marine natural products. Kishore is currently testing the antibiotic against different human pathogenic bacteria.

Because bacteria are continually developing resistance to antibiotics, the world is currently in an arms race against pathogenic bacteria. Dr. Keiji Fukada, the Assistant Director-General for Health Security at the WHO, says that if action is not taken, "common infections and minor injuries which have been treatable for decades can once again kill."

Kishore is well aware of the urgent need for novel antibiotics and is excited to be a part of the fight. "If we run out of effective antibiotics," she notes, "even simple surgeries like appendectomies can become life threatening."

April 29, 2021

WHAT WE'VE LEARNED FROM JUNO'S LATEST LAPS AROUND JUPITER

Written by Lydia Guertin

Edited by Catherine Kim and Hedy Goodman

Jupiter's (cyclonic) south pole, taken by the Juno spacecraft. NASA, 2017.

You may have seen the gorgeous pictures of Jupiter floating around your twitter feed, but they only scratch the surface of the incredible discoveries the Juno spacecraft has sent back to Earth. "Every 53 days, we go screaming by Jupiter, get doused by a fire hose of Jovian [pertaining to Jupiter] science, and there is always something new," says Scott Bolton of his experience as principal investigator aboard the 10-year-old Juno mission.

Since July 4, 2016, when the Juno spacecraft was close enough to Jupiter to complete one orbit every 53 days, Bolton has overseen data collection and analysis from each of the eight instruments aboard Juno, including optical, infrared, and ultraviolet telescopes. The data files are so large that they can take over a day to transmit to Earth and much longer to analyze.

Juno was designed to answer our basic questions about Jupiter, a planet relatively close to Earth in our solar system. These include the composition of its prominent cloud formations and how its extraordinarily strong magnetic field — second only to the sun in our solar system — affects its moons and emission at different wavelengths. The spacecraft's elliptical orbit enables mapping of the core mass distribution, the pressure-varying gravitational field and polar magnetic field and aurorae — all of which inform us of Jupiter's formation and evolution.

The first results from the Juno mission were released in October of 2016, revealing that the depth of the colorful stripes of clouds is much deeper than scientists had theorized. The infrared telescope aboard Juno captured pictures of the planet's deeper layers, confirming the continuation of the gaseous stripes beneath the visible outer surface. September 2017 brought yet another discovery, and with it, an entirely new field of study focusing on Jupiter's magnetic field. Jupiter's auroras, which are not actually visible at optical wavelengths, puzzle scientists in their formation, as they are unlike that of the northern lights we experience on Earth. However, upon comparisons with the Voyager results — another NASA mission to pass Jupiter — researchers connected the observed "torus," or ring, of plasma around Jupiter's equator to be the source of the charged particles that produce aurorae at Jupiter's poles.

Recently, the Juno mission has been winding down, completing its last few orbits before it deorbits into Jupiter in July 2021. Though its time of actively collecting data will soon come to an end, the impact of the Juno mission will continue to be seen as researchers analyze and present its data for years to come.

May 5, 2021

A NEW FRONTIER: SCIENTIFIC FUNDING POLICIES AFTER COVID-19

Written by Lydia Guertin

Edited by Lucy Zhao and Anagha Aneesh

Federal research and development funding has become a hot-button issue after the Trump administration defunded Predict, a pandemic early warning project that had already identified and flagged 190 dangerous coronaviruses, just months before the global outbreak of COVID-19. In the 2019 fiscal year, federal research and development (R&D) funding was sitting at less than 1% of the US national gross domestic product, the lowest in over 60 years.

Because of this decreased funding specific to health and viral research, it was no surprise that the US was unprepared to face the COVID-19 pandemic, one of the biggest health crises of the 21st century. The infrastructure necessary to support the increased need for research on this new virus, public health policy development, and expedited vaccine development did not exist.

"[T]he present pandemic has also revealed that science underpins a country's national security in ways never appreciated before," says Dr. Geoffrey Dobson, former NIH cardiovascular researcher. "The resultant economic upheaval has thrown global supply chains, stock markets, the airline industry, oil markets, and the central bank into frenzied disarray." More than ever, the world has seen the importance of science in our society, thereby increasing public attention to exactly how scientific programs are funded at the federal level.

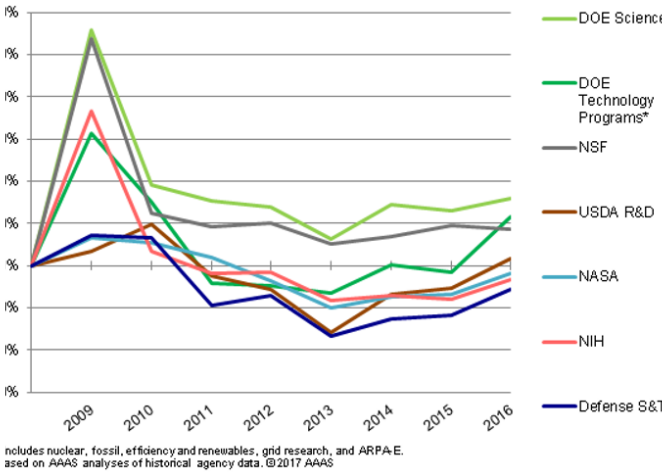
Federal R&D funding was a major component of the Obama administration, and its primary goal was to improve sustainability and renewable energy prospects. In his inaugural speech, former President Obama promised to "restore science to its rightful place" in America by returning to the basics of scientific funding and promoting scientific education in schools. The Obama administration subsequently pushed to double federal scientific funding, specifically in the areas of cancer research and basic research, setting a high bar for his later years that would not be reached again.

While the Obama administration created a net increase in funding for basic Department of Energy science programs and the National Science Foundation, most other major government-funded scientific programs saw only a brief increase during his early years in office, later dropping to the same level of funding before the Obama administration.

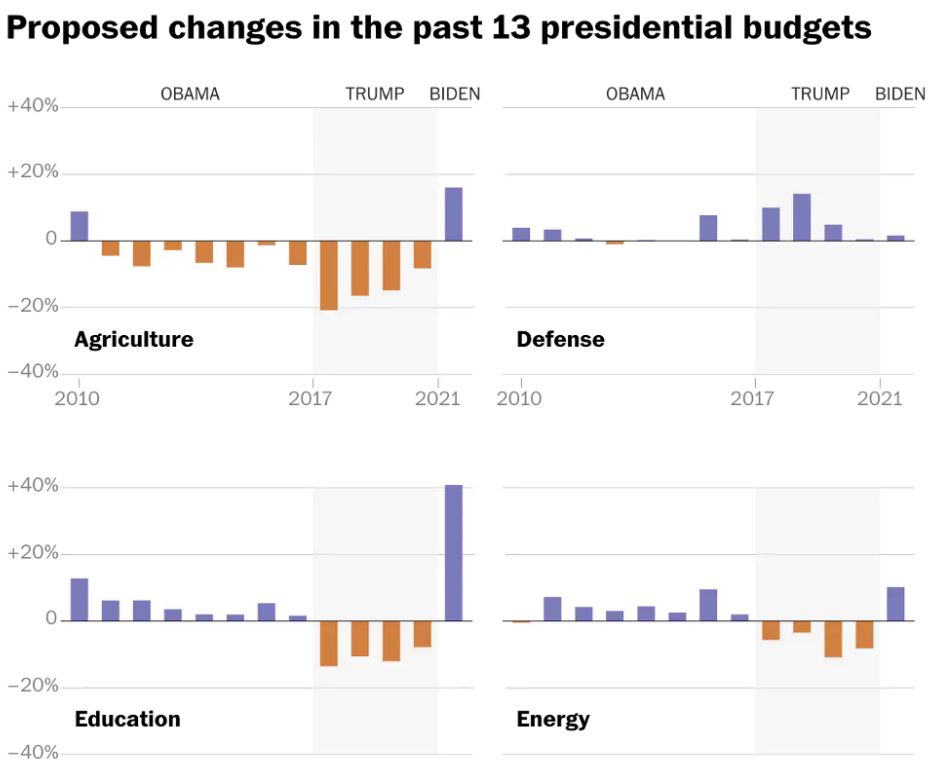
In the Trump administration, scientific institutes were targeted for significant decreases in funding, with the Department of Defense technology R&D favored at the expense of basic and applied research. However, despite the best efforts of the Trump administration, the sitting Congress continued to push forward a mixed batch of budget increases, including significant increases for the National Institutes of Health and that National Oceanic and Atmospheric Administration.

These increases prioritized funding for research on neurodegenerative disease and climate science, considered pressing issues for the American public. However, the inclination to allocate funds based on current problems significantly decreases the resources available for unforeseeable situations, such as a global pandemic. Without this funding for basic and applied scientific research, which often don't have a specific problem-resolution end goal, we inadvertently narrow the scope of preparedness for the unforeseen.

Much of basic research does not have an immediate practical application. As a result, funding for this kind of research, co-founder of Microsoft Research Nathan Myhrvolt says, is viewed as a form of charity by many corporations and governmental organizations, as it does not directly enhance a product or pressing issue.



American Association for the Advancement of Science, 2017. Matt Hourihan.



Budget of the U.S. Government. Via the Washington Post, 2021.

Myhrvolt asserts that "[without] government support, most basic scientific research will never happen," as corporations aren't known for their generosity, especially when it will not benefit them or their products. This is perhaps most true for the huge scientific developments that bring prestige and advancement without profit, such as mapping the human genome. These advancements are still enormously valuable, but are often unlikely to receive funding under the categorization used by many government committees, including the Trump administration's budget plan.

Myhrvolt's line of reasoning is the same one which led to the cutting of the Predict early pandemic warning project just before COVID-19 hit: though the project had identified potentially dangerous viruses, there seemed to be no reason to continue an expensive project with such small prospects of actually predicting and preventing a global pandemic.

While the outlooks of such lines of reasoning and patterns of funding seem grim, the post-COVID-19 funding policies appear to be taking a different approach. Under the Biden administration, there have already been aggressive strategies adopted to both destigmatize science education and invest in the nation's future through R&D funding. In the proposal for the 2022 fiscal year, the Biden administration outlines significant increases to the Department of Energy and the Department of Education, specifically increasing the Department of Energy R&D budget by 10.2%, allocating funds for physics research, running supercomputers, and national laboratory funding.

Within these increases, there is also a $250 billion proposal specifically for scientific research, including $40 billion directly for upgrading research facilities across the country, in both universities and national laboratories. These funds are allocated for more general basic and applied scientific research, a departure from the previous administration and an encouraging sign of investment in the advancement of science for knowledge, not just for monetary gains.

While there have been attempts to cut important scientific programs and broader funding of basic scientific research in the past three administrations, there are now hopeful outlooks for the future of federal research and development funding. The COVID-19 pandemic has pointed out glaring failures in past administrations' funding policies, especially for programs not directly linked to solving current problems, and it appears the new Biden administration has begun taking steps to address this gap.

June 1, 2021

SUMMER STARGAZING: BLACK HOLES AND SHOOTING STARS

Written by Karen Masters, Professor of Astronomy and Physics at Haverford College

Edited by Emi Krishnamurthy and Lydia Guertin

The summer is one of my favorite times for stargazing. The nights are short but warm, and many people spend time camping — an ideal activity to mix with stargazing. Try looking for Sagittarius, Mercury, Jupiter, Saturn, meteor showers, and even a partial eclipse of the sun this summer. You can see almost everything I suggest below without any equipment.

Sagittarius is one of my favorite summer constellations to look for. Greek astronomers saw a centaur firing an arrow, but I always look for the teapot. At a dark enough site, you can even see the steam coming out of the spout — what you are actually looking at is the Milky Way. This part of the night sky looks cloudy because there are so many faint stars close together. You are actually looking towards the center of our own galaxy and the supermassive black hole "Sagittarius A*" that lives there. The further south you go, the higher Sagittarius will be in the sky. Where I grew up, it was always quite low in the summer skies.

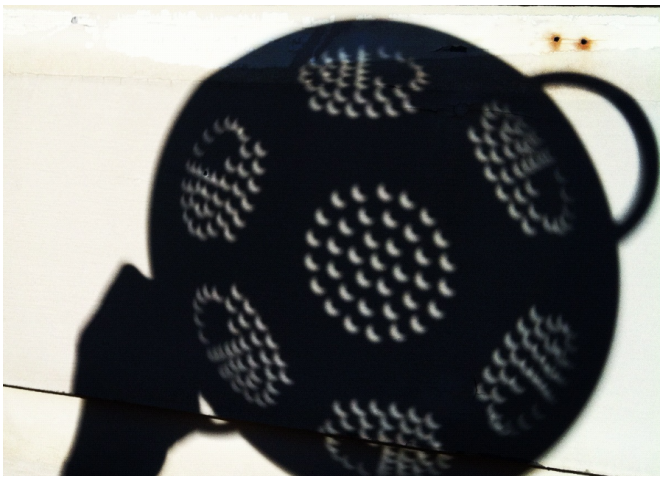
Some of the planets put on a show this summer. In early July, Mercury will reach its point of "Greatest Western Elongation," which means that it is at its largest apparent separation from the Sun, and it's the best chance you have to see it visible in the evening (just after sunset). Mercury is one of the most challenging planets to catch, because it's always so close to the Sun, so this is a great opportunity. For a bonus, on July 11th/12th you will be able to see it next to both Venus and the crescent Moon.

The outer planets Jupiter and Saturn will also be prominent in late-summer evenings. Both will be passing through "Opposition" in August (on the 2nd and 19th respectively). What this means is that they are directly opposite the Sun in our skies — they will rise right as the Sun sets, moving up as the night goes on, and they are the closest and brightest they will appear for a while.

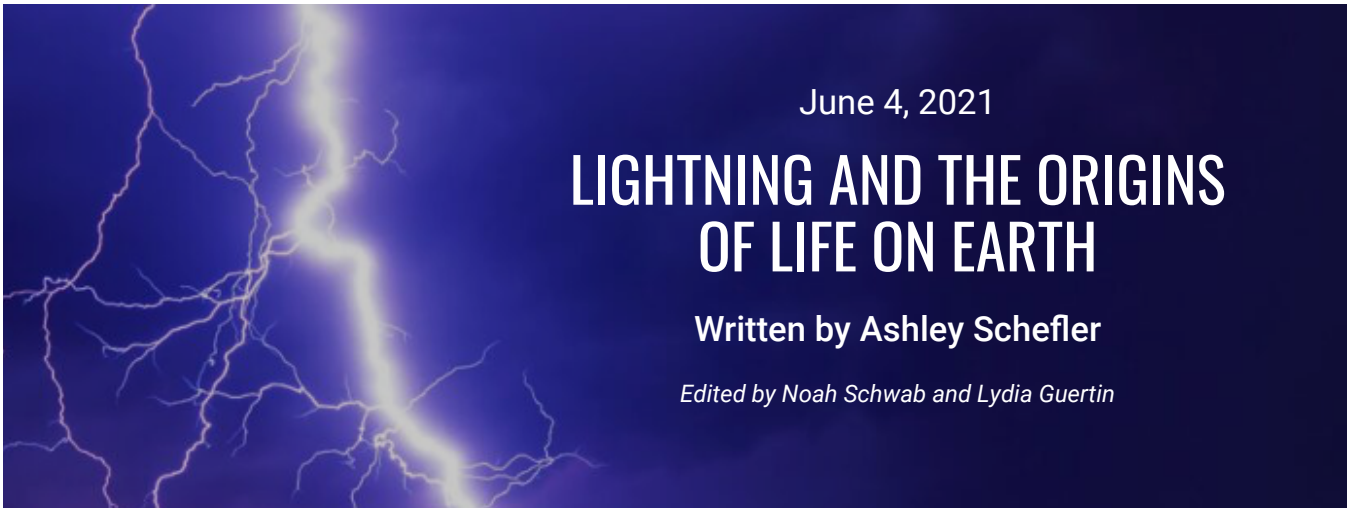
Real image of the Milky Way with the "Teapot" marked (Canada). By Trevor Jones, "The Astrophotographer"

Meteor showers are a popular summer stargazing activity. During these events, you will see several "shooting stars" as the Earth passes through debris left behind from a comet so small that as lumps of material enter our atmosphere they burn up completely. The Delta Aquarids shower is predicted to peak July 28th/29th, and the Perseids shower Aug 12/13th. Perseids is usually one of the best meteor showers of the year, with typical rates of one meteor per minute. The best way to watch a meteor shower is to sit outside and get comfortable. Reclining chairs recommended…

My final suggestion is the only one that requires equipment and is for early risers only. On the morning of June 10th, there will be a partial eclipse of the Sun as it is rising across the East Coast of the US. In Philadelphia, the sun rises at 5:31am that morning, and the partial eclipse ends at 6:30am. You should never look directly at the Sun without a solar filter (i.e. eclipse glasses), but if you don't have eclipse glasses, a colander can be used to great effect to project shadows of the crescent Sun. Stand with your back to the Sun, and look at the shadow cast by the colander.



Pinhole projection of a solar eclipse using a colander. Photo by Alice Pintus.



June 4, 2021

LIGHTNING AND THE ORIGINS OF LIFE ON EARTH

Written by Ashley Schefler

Edited by Noah Schwab and Lydia Guertin

Phosphorus is an essential element for all life on Earth. Without it, we would not have the DNA that stores our genetic information, the ATP that provides energy for chemical reactions, or the phospholipids that make up our cell membranes. While phosphorus is abundant in Earth's rocks, it is present in an oxidized form that makes it unreactive, and is therefore inaccessible to biological organisms. So how did early life on Earth gain access to phosphorus?

Until now, the prevailing theory has been that meteorites brought phosphorus to Earth in the form of the mineral schreibersite, a phosphorus-rich compound that dissolves in water, yielding reduced phosphorus. The difference between this reduced phosphorus and the oxidized phosphorus in many of Earth's rocks is the charge on the atom, which makes this reduced atom able to react to form biomolecules while the oxidized atom cannot.

There are a couple of problems with this meteorite theory. First, the frequency of meteorite strikes was declining as life emerged on Earth. Second, the force of a meteorite impact could kill off any nearby lifeforms or vaporize the phosphorus-rich schreibersite before it could be used.

A study published in Nature earlier this year suggests an alternative source of reduced phosphorus for early life: lightning. Lightning strikes can form glasses called fulgurites, which this study found to contain schreibersite, particularly in clay fulgurites with high concentrations of graphitic carbon. Fulgurites can also contain reduced phosphorus as part of other compounds, even when there is no schreibersite present.

The researchers created a mathematical model to determine how much reduced phosphorus would have been produced by lightning strikes versus meteorites over time. They used available data on historic concentrations of CO_2 to predict the frequency of lightning strikes. This correlation occurs because CO_2 increases the temperature of the atmosphere, allowing more water vapor to collect. Lightning is formed by charge separation within fast-moving clouds, with water vapor as the fuel for this process. Thus, as an oversimplification of a phenomenon that climate scientists are actively studying, more CO_2 means more water vapor means more lightning strikes. Combining CO_2 data with their fulgurite analysis, the researchers were able to determine how much reduced phosphorus was produced by lightning strikes and compare that to what previous studies had determined was produced by meteorites. They concluded that lightning strikes were a source of reduced phosphorus as significant in size as meteorites when life was emerging some 3.5 billion years ago.

This research has important implications in understanding the development of life on Earth as well as informing our search for life on other planets. Lightning provides a source of phosphorus that remains constant over time and is far less destructive than meteorite strikes, enabling the development of life in shallow water environments such as those on early Earth and those being studied on Mars.

A fulgurite on display in the Iwamizawa Folk Science Museum. Photo by SelEle-MS, CC BY-SA 3.0, via Wikimedia Commons.

June 9, 2021

BARK BACTERIA MAY LIMIT TREE GREENHOUSE GAS EMISSIONS

Written by Emi Krishnamurthy

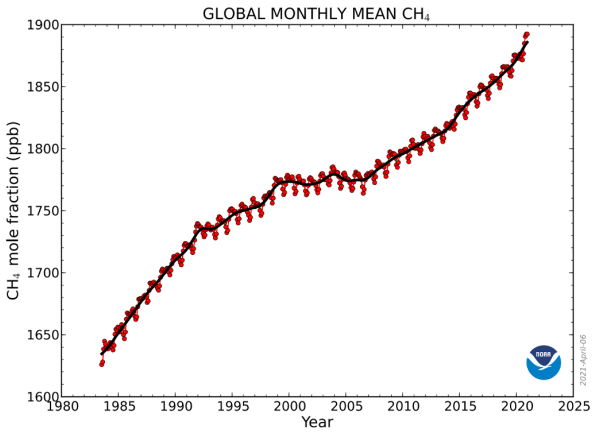
Edited by Lydia Guertin and Ashley Schefler

Wetland trees are an unexpected but major source of global methane emissions. Methane-oxidizing bacteria recently discovered in tree bark could inform how climate scientists and legislators approach future methane mitigation strategies.

Methane comprises 10% of greenhouse gas emissions in the United States, but can be 32-87 times more potent than carbon dioxide at warming Earth's atmosphere. Natural sources produce millions of metric tons of methane every year because of climate change feedback systems, with wetland forests contributing about a third of total methane emissions worldwide. This may be startling to some, as trees are widely known to offset greenhouse gas emissions, but this isn't a new discovery.

In 1907, Francis Bushong was surprised to discover that he was able to burn a sample of cottonwood tree sap. Upon further analysis, he found that methane made up about 60% of the gas produced by cottonwood trees. Bushong published his research in the Chemical and Physical Papers journal in 1907. Interest in Bushong's findings waned throughout the century, but today, as the world's eyes focus on climate change, increasing numbers of scientists are measuring methane emissions from trees.

Paperbark Trees in Coombabah Lake Conservation Park. Photo by Silverish Lily via Wikimedia Commons. CC BY-SA 4.0.



Global monthly averages of methane emissions. Figure via National Oceanic and Atmospheric Administration.

methane emissions mostly come from coal, natural gas, and oil production and transportation; livestock; and agriculture, according to a 2019 EPA report. Wetland forests contribute about one-third of global methane emissions, yet global climate and greenhouse gas mitigation policies have ignored them as a main methane emitter, as reported by a 2017 paper by the Potsdam Institute of Climate Impact Research. Methane emissions from wetlands have also increased due to changing global wetland area and the temperature-sensitivity of methane.

Fortunately, certain wetland tree bark contains bacteria that can reduce the tree's methane emissions, according to a discovery reported earlier this spring in Nature. For the first time, scientists were able to show that tree bark may be a host to methane-oxidizing bacteria, which consume methane as their energy source and produce other forms of carbon as a byproduct. The team examined the bark of Melaleuca quinquenervia, a wetland tree also known as the paperbark tree, and found that bark-dwelling, methane-oxidizing bacteria reduce paperbark tree methane emissions by almost 36%.

The researchers state that "if [methane-oxidizing bacteria] are a ubiquitous feature within the bark of methane emitting trees, our conceptual understanding of the global methane cycle may need revision." Many corporations are demonstrating their environmental responsibility by planting trees to offset their carbon emissions. While in most cases, trees' carbon absorption outweighs their methane emissions, we may need a better and more nuanced understanding of the exact dynamic.

Although further research is needed, especially with regard to different species of trees that hold methane-oxidizing bacteria, this research is a stepping stone for scientists and policymakers to better understand and mitigate tree methane emissions, particularly considering oft-overlooked wetland emissions.

June 12, 2021

INGENUITY: THE FIRST POWERED FLIGHT ON MARS

Written by Hannah James

Edited by Catherine Kim and Lydia Guertin

NASA's Ingenuity Mars Helicopter on the belly of the Perseverance rover, ready to be dropped off at the helicopter's deployment location. Photo by NASA.

Ingenuity, which landed on Mars in February 2021, is the first powered aircraft to take place on Mars. Exploring Mars from the air gives scientists a unique perspective: they will be able to survey Mars' geology in ways never attempted before.

The Perseverance Rover has recently made headlines as the most recent rover to be sent to the red planet. Its main objective is to detect signs of life and to collect rock and soil samples. However, rovers can't go into areas that are too steep or slippery, so Perseverance didn't make this venture alone: attached to its belly was the Mars Helicopter Ingenuity, an autonomous aircraft only 19 inches in height with a 4-foot rotor system wingspan. Ingenuity, along with Perseverance, was launched July 30th, 2020 and landed on Mars on February 18th, 2021.

Ingenuity's mission is completely separate from Perseverance and experimental in nature. Once Perseverance finds a reasonable helipad location, Ingenuity will be released and then perform a series of test flights over the next 30 Martian days, beginning in early April. Months after landing on the Martian surface, Ingenuity will test powered flight in the Martian atmosphere for the first time ever. This is groundbreaking because Mars has about one-third of Earth's gravity, yet its atmosphere is 15 times as thick, making it difficult to generate lift.

Ingenuity has two other objectives. The first is to demonstrate miniaturized flying technology, which required scientists to shrink onboard computers and electronics so Ingenuity would be light enough to be able to take off. The second objective is to show that Ingenuity can operate autonomously. Once Ingenuity has received commands from Earth, which are relayed through Perseverance, every flight will be performed without real-time input from mission controllers.

The first flight on April 19th, 2021 took Ingenuity off a few feet from the ground and held it in the air for 20-30 seconds before landing. After this first powered flight in the atmosphere of Mars, further test flights will occur, incrementally increasing in both distance and altitude.

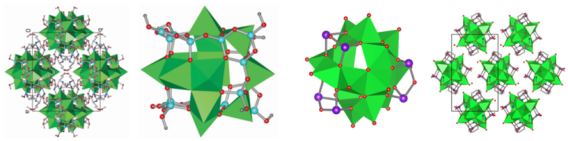
Ingenuity is reaching milestones and is becoming a key part of the future of Mars exploration. How Ingenuity performs during the test flights will inform other decisions about small helicopters for future missions on Mars, as there are many ways that a small helicopter could be used on Mars. Helicopters could perform as a support to rovers, acting as robotic scouts to survey the Martian terrain from above, or as standalone crafts that could carry instrument payloads. In the future, helicopters may also assist astronauts in exploring Mars, accessing difficult-to-reach places.

June 14, 2021

CRYSTAL SYNTHESIS: A SNEAK PEEK INTO THE NORQUIST LAB

Written by Asher Maitin

Edited by Joe Ding and Anagha Aneesh



The work done in Alex Norquist's Chemistry Lab at Haverford College involves both the synthesis of novel compounds with exciting properties as well as addressing inequalities in material chemistry datasets. For instance, some materials can be used for material synthesis but are not due to various human-driven biases and decisions. One example is the material availability bias, referring to the cost of a material, or how readily available the material is to locate and use.

The Norquist Lab at Haverford is divided into several different projects, all pertaining to material chemistry and machine-learning, which can be used to address the inequalities to generate higher quality data. I will be describing the Oxide Project. Yong Suk Choi ('21), Matthew Danielson ('21), Joshua Engler ('22), George Jiang ('22), Davion Williams ('23), Teddy Carlin ('24), and myself are currently working on this project.

While our lab primarily focuses on unbiased exploratory chemistry, a result of exploration is the discovery of new compounds, particularly small, observable single crystals. What are crystals? Crystals and crystalline solids are materials with highly ordered structures. On a microscopic level, they form a repeating structure of units called a lattice. The crystals and crystalline products synthesized in our lab are particularly interesting to study due to their wide structural diversity, as many different elements from the periodic table can be implemented into these structures. By experimenting with new reaction conditions and infrequently used reagents, we may be able to actually generate novel compounds with new bonding, symmetries and shapes.

The "Oxide Project" focuses on the unbiased synthesis of "Organically Templated Metal Oxides." Huh? Let's break it down. A metal oxide is a compound consisting of two elements: a metal element and oxygen. Metal oxides are unique crystalline solids that form polymeric structures with strong bonding. Organic compounds are chemicals whose structures are largely made of hydrogens and carbons, potentially with some heteroatoms — that is, non-hydrogen, non-carbon atoms — such as nitrogen, oxygen, and sulfur. The introduction of heteroatoms in the structure often determines specific chemical behaviors and properties of the compound.

One common type of organic compounds are amines, which contain nitrogens. In our project, we use different forms of amines as a key reagent in the synthesis of novel compounds. Amines aid in the formation of the crystalline template by situating themselves in special locations in the repeating lattice structure. All together, these compounds are known as organically templated metal oxides.

As much as the Oxide Project group desires to generate crystals, we are also working with combinations of materials, or systems, that are largely unreported in published literature. In fact, recent research conducted by the Norquist Lab suggests the existence of large gaps in the choices of which reagents, more specifically, amines, chemists often use for crystal-forming reactions. In other words, many amines exist that can be used in such reactions, but few actually are. This is a significant finding that needs to be addressed if continuing with exploratory chemistry.

> ***The Norquist Lab has previously successfully developed a machine-learning program that provides insight into promising reagents that are not found in published literature.***

In response to this discovery, our lab generates randomized reactions with unpopular reagents to determine if these materials are just as likely to produce organically templated metal oxides as those frequently reported in published literature. The basic idea is that computer-generated reactions — "randomized reactions" — are free from human bias, which allows us to explore systems that are avoided by most chemists for no legitimate reason, and thus gives us better insight into which reagents may provide successful results. Yet, given that human researchers always have to decide whether to adopt the results of computers or not based on their own judgments, the exploration process can be tricky sometimes.

Using the data from our randomized reactions, the Norquist Lab has previously successfully developed a machine-learning program that provides insight into promising reagents that are not found in published literature. This program incorporates data from combinations of reagents and reaction conditions that resulted in both successes and failures. The machine-learning approach has the capability to save time and resources.

June 14, 2021

RUSSIA'S NEUTRINO DETECTOR: A NEW REALM OF HIGH-ENERGY PARTICLE PHYSICS

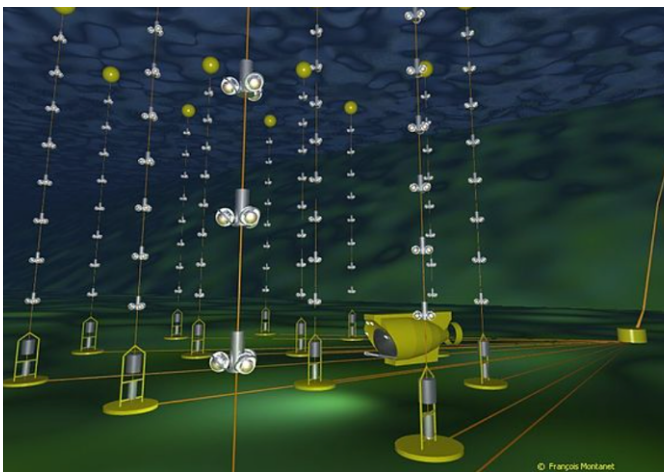
Written by Lydia Guertin

Edited by Joe Ding and Sam Tan

Some of the biggest mysteries in modern astronomy involve the emission of neutrinos, including high-energy astrophysical events like supernovae and black hole formation that also emit high-energy light in the form of gamma rays. These neutrinos are subatomic particles that interact very weakly with their surroundings, so they can only be observed using very sensitive telescopes, complicating the process to observe them.

To further the studies of extreme phenomena like black holes, rapidly-rotating neutron stars called pulsars, and galaxy merger events, where two galaxies collide, scientists in Russia recently launched a new neutrino telescope into the depths of the world's largest natural lake: Lake Baikal.

Neutrino telescopes are very different from other types of telescopes in that they must be submerged in water or ice. We can't detect neutrinos in air because neutrinos rarely interact with their environments, unlike the electrons that produce emissions on the electromagnetic spectrum, ranging from visible light to gamma rays. Instead, neutrino telescopes detect very faint traces of Cherenkov radiation, a different kind of emission, as neutrinos pass through different mediums, usually water here on Earth.



Setup view of the Antares Neutrino Telescope, François Montanet Via Wikimedia Commons.

Panoramic view of Lake Baikal seen from Olkhon Island. Photo by Sergey Pesterev via Wikimedia Commons.

Since neutrino telescopes can only detect traces of Cherenkov radiation through water, the depth and size of the water they are submerged in determines the size of their detection area. Thus, the new Russian telescope will have the largest detecting area of any neutrino telescope currently on Earth because of the sheer size of Lake Baikal. This is crucial, as super high-energy events such as extreme solar flares and star core collapses have recently been shown to correlate with increases in neutrino emissions, a trend that our current knowledge of neutrino emissions can't yet explain. We still lack understanding of how exactly neutrinos are produced, so observing more of these emission events is a necessary step in understanding what happens in these high-energy events.

Neutrinos are also a candidate for dark matter, an unknown form of matter that can't be seen, but rather is observed through its effects on the gravitational forces in large systems like galaxies. These particles fall into a category called WIMPS, or Weakly Interacting Massive Particles. While neutrinos by themselves are quite light, as they are subatomic particles, together they are thought to comprise a significant portion of the unknown dark matter mass in the universe. Since we don't know the specific processes of neutrino emission, it is nearly impossible to make an estimate of the population of neutrinos in our universe. Because of this, we have no way to tell if neutrinos actually do make up a significant enough amount of matter to be considered a similarly significant portion of dark matter until we understand how frequently these neutrino emission events happen.

This new neutrino telescope could hold the key to unraveling the mysteries behind neutrino emissions, especially given its large detecting area. Once we are able to study neutrino emissions more thoroughly with the new telescope, we can narrow down the current dark matter candidates and expand our knowledge of extreme physics.

June 18, 2021

HOW QUICKLY IS THE UNIVERSE EXPANDING? THE HUNT FOR THE TRUE HUBBLE CONSTANT

Written by Lydia Guertin

Edited by Hedy Goodman and Emi Krishnamurthy

It is now a well-known fact that the universe is expanding, but how quickly is it growing? Despite decades of cosmological research across the globe, no astronomer can definitively identify this rate of expansion, the Hubble Constant H_0. Such uncertainty stems from Hubble Tension, the quantitative difference between two different methods used to calculate H0. Luckily, Dr. Bruce Partridge, one of the original collaborators on the Planck Satellite team, is an Emeritus Professor of Astronomy here at Haverford College — and he was excited to explain this puzzle.

As soon as we can determine the true value of H_0, our understanding of the universe and how it has changed from its birth to now will become much more refined, allowing us to further develop our theories of dark matter, universe inflation and expansion, and measurements of light from distant objects.

What is the Hubble Tension?

If we've been trying to measure the expansion of the universe for so long, what's stopping us from landing on a definitive value? Partridge says the answer lies in a discrepancy in the way we measure expansion locally versus distantly. The basic equation to find H_0 gives a measure of an object's changing speed as its distance from Earth increases. However, this can be measured using either present-day values of distant objects and their velocities, which would give an H_0 in this current space and time, or using values from the Cosmic Microwave Background (CMB). Since the CMB is a map of early universe temperatures, which can tell us about characteristics of that time and space, using its values will yield an H_0 from the earliest stages of the universe.

> "Needless to say, the supernova [local value] folks think there are problems with the CMB measurement, and vice versa." – Dr. Bruce Partridge

Using both methods as well as the temperature of the CMB left over from the Big Bang (T_0), astronomers have found that the H_0 calculated from the CMB and its assumed T_0 is roughly 10% larger than the value calculated from local measurements, which is far greater than any reasonable error. This disparity is called the Hubble Tension.

Shouldn't these values be the same? How can this happen?

Partridge says there are a few posited explanations for the discrepancy: "[t]he simplest is that one of the values is wrong, because of some subtle error in measurement that we haven't uncovered yet. Needless to say, the supernova [local value] folks think there are problems with the CMB measurement, and vice versa. That is why there is so much interest in some new, third way to measure [H_0] — to break the tie."

In addition to these theories, some say there is simply an inherent difference in the local and CMB values of H_0, which would imply that there is something fundamentally wrong with our understanding of the universe—or alternatively, something is lacking. There have been several proposed solutions to this inherent difference, including a form of dark energy that fades after the creation of the CMB (see also: What is Dark Matter? By Hannah James).

More recently, and more contested between the local and CMB projects, is the suggestion that our measured and calculated value for T_0 — the temperature of the CMB — is incorrect. Due to the influence of T_0 in the calculation of the Hubble Constant, if T_0 = 2.55K instead of the currently accepted value of T_0 = 2.726K, the local and CMB values of H_0 would match. However, as Partridge notes, "[s]o far, none of these alternative explanations involving new science have worked. Some can indeed explain away the tension in [H_0], but they introduce other discrepancies with the data. One example is the suggestion that [T_0] is wrong. There are several, independent ways of measuring [T_0], and they agree on 2.726K, not a lower value." Dr. Partridge's own research has confirmed this value of T_0 multiple times, one of which involved a pair of Haverford students, Benjamin Walter '13 and Gerrit Farren '20, who confirmed the calibration of the Planck satellite. Since the Planck satellite was Europe's first mission solely to define and constrain the age of the universe and its early characteristics, including composing a full map of the CMB, this confirmation was an important step in ruling out errors in our estimates of T_0. He also notes that several other methods of measuring T_0 favor the CMB value, indicating that this discrepancy in T_0 would, if anything, favor the CMB value of H_0 .

Understanding the Hubble Tension is incredibly important for both understanding early cosmology and how our universe works today, including revising our theories of dark matter and the effects the expansion of the universe has on our measurements of light from distant sources. For now, as Partridge says, "we'll keep working on other explanations — and on checking our observational results."

June 21, 2021

WHAT IS DARK MATTER?

Written by Hannah James

Edited by Rebecca Stevens and Lydia Guertin

Dark matter is mysterious to many, and exploring this phenomenon usually leads to more questions than answers. Professors Dr. Karen Masters, associate professor of Physics and Astronomy, and Dr. Daniel Grin, assistant professor of Physics and Astronomy, provide key answers and explanations.

Dark Energy vs. Dark Matter

The first thing that both Professor Masters and Professor Grin want to make clear is that dark energy and dark matter are two very different things, even though they are usually lumped together.

Professor Masters says that dark matter is the name we give material that we see in galaxies. Professor Grin also mentions the gravitational effect of dark matter, stating that "dark matter is matter that fundamentally interacts with other matter through gravity." We know that dark matter exists because we have evidence of matter pulling on other matter with gravity, yet it doesn't give off light. Dark matter's name is rather misleading, Professor Masters points out. It is transparent rather than dark, and it doesn't absorb, produce, or reflect light in any way. Because of how difficult dark matter is to find, the identity of dark matter is still unknown. It really is a mystery!

Dark energy is very different. We know that the universe is expanding; however, this shouldn't be happening given what we know about gravity. Gravity should be slowing this expansion down, but instead, the universe's expansion is accelerating. This is due to dark energy, which Professor Grin says has a "negative pressure." Professor Masters also posits that dark energy could be a modification of gravity. What we can conclude, however, is that dark matter and dark energy are both still very mysterious to this day.

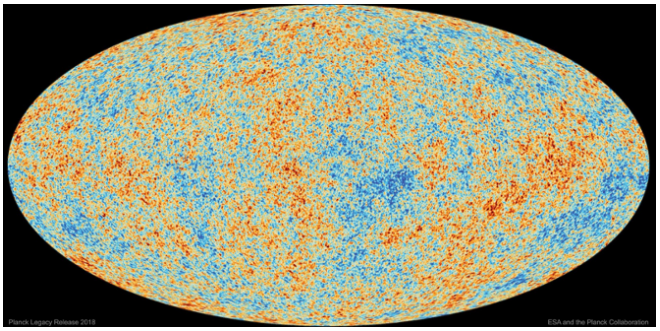
Dr. Karen Masters, Associate Professor of Physics and Astronomy (left), Dr. Daniel Grin, Assistant Professor of Physics and Astronomy (right).

This NASA Hubble Space Telescope image shows the distribution of dark matter in the center of the giant galaxy cluster Abell 1689, containing about 1,000 galaxies and trillions of stars. Dark matter is an invisible form of matter that accounts for most of the universe's mass. Hubble cannot see the dark matter directly. Astronomers inferred its location by analyzing the effect of gravitational lensing, where light from galaxies behind Abell 1689 is distorted by intervening matter within the cluster. Image and caption via NASA.

Professor Dan Grin's Research at Haverford

Professor Masters and Professor Grin are both completing research related to dark matter. Professor Grin explores cosmic microwave background radiation (CMB), which is electromagnetic radiation left over from the early universe. This shows a snapshot of the universe at 380,000 years old. The universe's current age is around 400 billion years, so this is one of the only ways we can see what the early universe truly looked like.

Examining sound waves in the CMB can reveal how clumpy matter is based on how hot or cold the waves are. The more dark matter there is, the clumpier normal observable matter seems. When looking at a map of the CMB, dark energy determines how wide and large these spots of sound waves are,



Planck Maps the Microwave Background. Image from European Space Agency, Planck Collaboration.

which can be used to determine how far light has travelled. The angular size of these spots gives insight into how quickly the universe is expanding and, thus, how much dark energy is hidden in this map.

Professor Grin compared CMB to a baby photo because it takes a snapshot of the infancy of the universe. He explained that if you look at this baby photo from a distance, you can figure out how far away it is by knowing the size of a baby's features and by using angles and geometry.

Professor Grin always loved how basic things, such as sound waves, harmonic oscillations, and the wave-particle duality can be used to explore abstract ideas. This is the case for CMB and exploring the concept of dark matter. Professor Grin is excited about the future of his research, and hopes to go from a 2D map of CMB and sound waves to a 3D map.

Professor Grin notes that his research is key in drawing a line between experimentalists and theorists. It helps push technology along, such as in precision measurements, which benefits both observers and theorists.

Professor Karen Masters' Research at Haverford

Professor Masters studies galaxies and their dynamics (how they move). She cites a useful analogy often used in the field: Imagine you take a photo of a crowd. How does the crowd change over its lifetime? Notice individuals' hair colors and heights. Professor Masters essentially takes measurements of people in the crowd and studies how they change over time.

Professor Masters also studies galaxies' rotating disk of stars. This rotation width is much too large for the stars in the galaxy. Therefore there must be something else in the galaxy — dark matter.

Professor Masters highlighted that galaxies with more stars relative to its dark matter halo act differently to those with fewer stars. She also pointed out that some galaxies have a galactic bar and some don't. A galactic bar is a line across the disk of a galaxy. Dark matter affects whether a galaxy will have this bar or not. A galaxy is more likely to have this bar if there are lots of stars compared to the dark matter halo in a galaxy.

Professor Masters has always had an interest in physics and cosmology. However, it was Vera Rubin who helped Professor Masters realise her interest in galaxies and dark matter. Vera Rubin and her calculations showed that galaxies contain about ten times as much dark matter than can be accounted for by the stars that we can see. Therefore, at least 90% of the mass in galaxies, and the universe, is invisible and unknown. Professor Masters is planning on continuing her research and is very excited about the data being taken with the Greenbank telescope.

Both Professor Masters' and Professor Grin's research not only helps people in their field, but also the wider scientific community. Professor Masters also explains that Astronomy is part of what makes us human, and that human curiosity is what drives people to want to explore the sky above. If it wasn't for astronomy research, we wouldn't have WiFi, GPS, or camera phones. Without knowledge of general relativity and its effects, GPS systems would be universally incorrect by about 20 meters.

Further Reading

Now that dark matter and its links to research at Haverford College have been explored, you may be asking yourself where you can learn more. People with no science background at all can learn and understand dark matter. Professor Masters suggested looking at Phil Plait's crash course in astronomy as a good place to start. It is used in 101 astronomy courses at Haverford and is rich in scientific knowledge. Professor Masters also suggested reading "Dark Matter and The Dinosaurs" by Lisa Randall (available in the Tri-Co Libraries). These are two accessible resources for people looking to expand their understanding of dark matter.

Professor Grin also recommended some informative TED talks by Risa Wechsler and physicist Patricia Burchat. If you would like to learn more about his research exploring the identity of dark matter as axions, he suggests watching "Are Axions Dark Matter?" from PBS. You might also explore Chanda Prescod-Weinstein's book, The Disordered Cosmos: A Journey into Matter, Spacetime, and Dreams Deferred, which discusses dark matter and marginalized groups.

The world really is at your fingertips. So go out, explore your interests, and expand your mind!

June 25, 2021

REEF SHARK CONSERVATION: IS IT TOO LATE?

Written by Lydia Guertin

Edited by Catherine Kim and Emi Krishnamurthy

Sharks are commonly heralded as an important species in oceanic and reef ecosystems, serving as an indicator of reef health, fish populations, and even seagrass growth. However, few people outside of the marine research community have noticed the alarming decline in shark populations, especially on reefs, until now, when it may be too late.

A July 2020 report published in Nature shocked many coastal communities across the globe when it announced that 20% of the reefs observed had no sharks over multiple months of observation. Although evidence of shark population decline had been previously recorded, the complete absence of sharks from multiple reefs across numerous countries and oceans confirmed what environmental researchers had been fearing: many species of sharks are becoming functionally extinct in the wild.

While functionally extinct does not mean fully extinct, a population that is functionally extinct is either no longer viable or unable to perform its specific role in the ecosystem it lives in, effectively ruining the natural order of the food chain, decomposition, and other regulatory processes.

Reef sharks play a vital role in their ecosystems, so what happens now that they are functionally extinct? Since sharks are generally considered the apex predator of their worlds, their removal triggers a "mesopredator release," or increase in the populations of sharks' prey. For reefs, this means an increase in middle-sized, predatory fish populations and a subsequent decrease in the number of their prey, smaller marine herbivores.

Many fishermen may like the sound of a larger-fish-rich environment — a place perfect for commercial fishing efforts — but the herbivores that these mesopredators feed on are equally as important in the ecosystem of a reef, as they regulate seagrass and algae levels. Without herbivores' help to keep algae levels in check, the algae may grow out of control and suffocate young coral populations.

Since reef sharks are interconnected with the survival of young coral, protecting reef sharks is a crucial part of protecting our already-endangered coral reefs. In addition to the impact of coral reefs on marine environments, such as providing shelter and food for a plethora of species, over half a billion people rely on coral reefs for food, income, and shelter.

Blacktip reef shark. Shot by Talon Windwalker via Wikimedia Commons.

The functional extinction of reef sharks affects more than just reef environments. According to the 2020 report, there was a clear correlation between the size of nearby markets — places dependent on fishing and other marine trades — and smaller reef shark populations. This correlation is attributed to the alarmingly high rate of "by-catch," which occurs when a shark or other species is unintentionally caught and killed by commercial fishing crews, and also to the growing demand for shark fin, considered a delicacy in many Asian countries.

Without these species of reef shark, both the fishing and tourism industries would suffer great losses. According to Oceana, a conservation effort based in Europe, one live reef shark can be worth over $250,000 over the course of its life as a result of diving tours, as compared to a one-time sale value of $50 when caught and killed. In addition, the negative effects of losing sharks in reef environments would decrease the value and attractiveness of those locations as tourist destinations, exacerbating the economic consequences on coastal markets.

Despite all these scary outlooks, the 2020 report was not all bad news. The report conveyed hopeful results about the effectiveness of "shark sanctuaries," no-dive zones, and other conservation efforts. Areas with these conservation measures ranked highest in reef shark populations. The report specifically suggests that socio-economic policies aimed at decreasing by-catch and limiting the amount of shark products that can be caught and sold would be especially effective at expanding and ensuring that reef shark populations are protected.

If implemented now, these measures could "begin to restore the populations of reef sharks around the world," the authors note, signaling that this report doesn't have to spell the end of reef sharks. With help from economic sanctions on the sale of endangered sharks and the establishment of ecological sanctuary spaces, reef sharks still have a long future ahead.

FALL 2021 – SPRING 2022

September 19, 2021

THE AMAZON RAINFOREST'S SINKING CARBON SINK

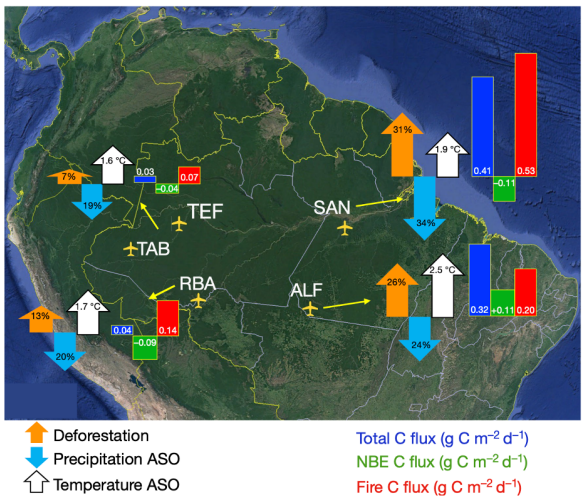
Written by Ashley Schefler

Edited by Emi Krishnamurthy

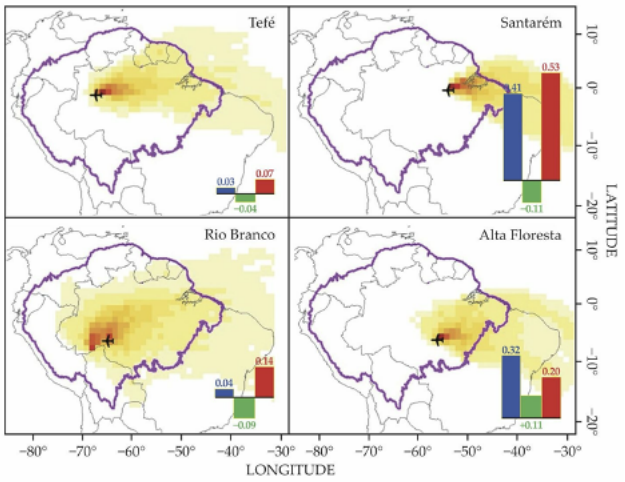
The Amazon rainforest is one of the world's greatest natural wonders. It is the largest tropical rainforest on Earth, spanning 2.6 million square miles (roughly 70% the size of the United States). The Amazon contains at least 10% of the world's known species, and, for many years, it has functioned as an important carbon sink. If you've been following the news on climate change, you probably know that trees are one of the good guys in the story, able to store some of the carbon that we emit and keep it from polluting our atmosphere.

However, according to a study published this summer by Luciana V. Gatti et. al., the Amazon has switched from being a carbon sink to a carbon source, releasing more carbon into the atmosphere than it takes in.

In the study, planes were used to sample the air above the Amazon, collecting data spanning nine years and four test sites. They measured carbon flux, which indicates how much carbon is entering or leaving an ecosystem, with positive values corresponding to net emission (a carbon source) and negative to net absorption (a carbon sink). Carbon flux caused by fires, often intentionally set to free up land, was isolated by tracking levels of carbon monoxide, which is emitted by fires. This



A map of deforestation, dry-season temperatures, and dry-season precipitation together with the average carbon fluxes from the previous figure. ASO stands for August, September and October. Figure by Gatti et al., "Amazonia as a carbon source linked to deforestation and climate change," Nature.



The figure above shows the four regions sampled in the study, with bars representing average carbon fluxes from 2010 to 2018. Carbon flux from fires is in red, carbon flux from the ecosystem is in green, and total carbon flux (adding the green and red bars) is in blue. Figure by Johanna L. Miller, "The Amazon is reaching its carbon tipping point" in Physics Today.

was set apart from the natural, biological carbon flux of the ecosystem, which involves factors like trees using up carbon dioxide in photosynthesis or bacterial and fungal decomposers releasing carbon dioxide as they break down dead trees and animals. They found that the total carbon flux was positive for all four regions they tested. Even more astonishingly, in the southeastern part of the Amazon, the ecosystem itself, even after removing the effects of fires, has become a carbon source.

So how did the Amazon become a carbon source? The answer is a combination of climate change and direct human interference. As the climate has warmed, the Amazon has become hotter and drier, particularly during the dry-season months of August, September, and October. Together with deforestation, this has created a degrading forest, where trees are either performing photosynthesis (the very process by which trees remove carbon from the atmosphere) at a slower rate, or just dying off.

These forces of climate change and deforestation are interrelated, working together to create a less healthy, less resilient ecosystem. For example, the forest needs evapotranspiration — water evaporation from plants and soil — to supply rainfall and cool the trees. The southeast portion, which has fewer lakes and rivers, is particularly reliant on this mechanism. Fewer trees means less evapotranspiration, increasing heat and drought in the area.

With the transformation of the Amazon into a carbon source, we have lost yet another asset in the battle against climate change, not to mention the direct danger to one of the greatest forests on Earth. As these natural ecosystems become less and less able to withstand the changing climate, the urgency of curbing our carbon emissions is greater than ever.

September 23, 2021

AUTUMNAL NIGHTS: THE FULL MOON AND EVENING STAR

Written by Karen Masters, Professor of Astronomy and Physics at Haverford College

Edited by Emi Krishnamurthy and Anagha Aneesh

The Full Harvest Moon from Vancouver in 2018. Image by Jeff Hollett via Wikimedia Commons.

As the evenings draw in, the Full Moon is a beautiful and accessible stargazing object. As is the case in the Spring, many cultures have festivals during the Fall that are set by the Lunar Calendar, and so they are explicitly or implicitly tied to the Autumnal Moons. For example, the date of Rosh Hashanah/Yom Kippur is set by the "lunisolar" Hebrew calendar, which means it (usually) starts on the date of the closest New Moon to the Autumnal Equinox (the date when night and day have equal lengths). Another example is the Mid-Autumn Moon festival — a very important date in many East and Southeast Asian cultures, which coincides with one of the Full Moons in the Fall. This year, it is the September 20th Full Moon.

Observant stargazers will notice the Moon is not up at night all the time. The Full Moon is specially accessible, as it is directly across the sky from the Sun, and therefore rises as the sun sets, making it a bright early evening object. Often the Full Moon appears to be incredibly large as it rises above the horizon. This phenomenon is known as "the Moon Illusion" and is a trick your brain plays as it processes visual information. The Moon is not actually any larger near the horizon, but it will often appear redder, as more of its blue light is scattered by the atmosphere.

Over the course of the month, the Moon moves closer to the Sun, until a New Moon happens when the Moon is in the same part of the sky as the Sun, and therefore both invisible and only in the sky during the hours of daylight. Sometimes the Moon passes precisely in front of the Sun, causing a solar eclipse — one of these solar eclipses will be visible from parts of Antarctica in early December.

Another type of eclipse is a "Lunar Eclipse" when the Earth passes between the (Full) Moon and the Sun. There will be a partial lunar eclipse visible from right here at Haverford very early in the morning of November 19th. During this event, the Moon may not completely disappear, but will take on a distinct red tinge, as most of the light from the Sun is blocked by the Earth. No special equipment is needed to view this event, which will look nice with the unaided eye.

If you have trouble keeping the types of eclipses straight, Astronomer Katie Mack created this helpful diagram, which went viral a few years ago on Twitter.

Via @AstroKatie on Twitter

Finally, Venus, as the "evening star" deserves a mention for stargazing this Fall. In late October it will reach its farthest apparent westerly distance (known technically as Western Elongation) from the Sun, making it a bright and beautiful point of light in the South Western evening skies. It should not be confused with the bright planet Jupiter (and the slightly dimmer Saturn) which are currently high in the South Eastern skies in the evening, and will appear to move closer and closer to Venus in the sky as the semester progresses (mostly because of the Earth moving in its orbit). All of these objects look great through our campus telescopes, and we hope you will be able to visit soon to look at them, but meanwhile enjoy the sites with your unaided eye.

September 26, 2021

HAVERFORD BEE HANDBOOK

Written by Emi Krishnamurthy

Edited by Ashley Schefler and Lydia Guertin

Bees run the world. They are widely recognized as being integral to biodiversity and food security. Their little lives impact our water cycle, carbon cycle, GDP, architecture, and so much more.

Honeybees

First and foremost, the honeybee is an excellent pollinator, skilled honey maker, and close friend to Haverford's campus. Our own beehive hosts thousands of fuzzy, golden-brown bees that help pollinate our produce at the Haverfarm. The honeybees you encounter on campus are most likely female worker bees collecting pollen and nectar from flowers so that they can return back to their nest and create honey. In the early summer, you might see male bees, called drones, which do not sting, collect nectar, or do any work for the hive; their sole purpose is to mate with the queen (and then they die in the mating process).

Honeybees can sting, but only once, and usually only if its life, nest, or queen is threatened. The verdict: Honeybees are friends, and if you see one, let it do its job and don't provoke it.

The Haverbees club, headed by Charlie Mamlin '23, aims to support pollinators in the greater Haverford community. This year, Haverbees plans to work with the Haverford to plant a native pollinator garden around the Haverfarm beehives. "Whether it be through education, action, or raising awareness," Mamlin says, Haverbees "is working to help the bees in our area so they can continue to help us in return."

Honeybee with pollen pockets on a yellow flower (left). Bumblebee on a purple flower (right), by Michelle Reeves via Pexels.

As a community, we cannot ignore that the world's honeybees are under serious threats. "There are more stresses on our honeybee populations today than there have ever been before," says Mamlin, adding that "the wide use of pesticides, global pollutants, and diseases and pests within the honeybee population have made it as important as ever to continue to support our bees in any way we can."

If you are interested in joining the Haverbees club and learning about how you can support our local bee populations, email haverbees@gmail.com or follow @hc_haverbees on Instagram!

Bumblebees

Another common social bee (bees that live together and interact with each other) on campus is the bumblebee. These fuzzy, round bees are also great pollinators — like honeybees, they collect pollen in baskets on their legs. Unlike the honeybee, they do not make honey, which is why we do not domesticate bumblebees. Although bumblebees can sting more than once, they are extremely docile and will only do so if their lives or nest is in imminent danger. The verdict: Bumblebees are also friends, but remember that they can sting repeatedly, so don't provoke them.

Carpenter Bees

Carpenter bees look like bumblebees, but they are much bigger and their abdomens are hairless. They are called carpenter bees because they make their nests by burrowing into wood, so they can be a huge pain for homeowners. Some males will mock "divebomb" if you get too close to its nest, but male carpenter bees don't have stingers (the females do). The verdict: they look big and scary, but they actually can't do much harm.

Carpenter bee (left), carpenter bee nest (right).

Hoverflies

Hoverflies look like tiny bees, but they are actually flies and cannot sting. The verdict: They can be annoying but are nothing to worry about.

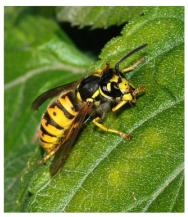

Hoverflies. Photos by Alves Gaspar via Wikimedia Commons.

Wasps

Wasps aren't technically bees. The most common types of wasps in Pennsylvania are yellowjackets, hornets, and paper wasps. Paper wasps and hornets build their nests above the ground, and yellowjackets build below the ground (though sometimes they build nests in places that resemble below-ground structures, such as in cracks in stone walls). They can sting repeatedly to protect their nests and hunt prey.

Some wasps are more docile and others are more aggressive, but I personally plan to avoid wasps in general. Yellowjackets love food scraps and sugary drinks, so beware when eating outside or picnicking on Founders! The verdict: do not swat the wasp!





From left to right: Hornet, European paper wasp, yellow jacket. Photos by Imortalcris via Getty Images, Ryan Hodnett via Wikimedia Commons, and Alves Gaspar via Wikimedia Commons.

The Asian Giant Hornet (a.k.a. The "Murder Hornet")

The Asian giant hornet is an invasive species whose queens can grow up to two inches. Although their stings can be fatal to those who receive multiple stings or are allergic to its venom, they are no more deadly than regular bees and wasps. Their main threat is not to us, but to our home pollinators — Asian giant hornets are known to decapitate and kill honeybees, ants, and other wasps, and they can even slaughter entire hives.



From left to right: queen of Asian giant hornet, European hornet, cicada killer wasp carrying a dead cicada. Photos by Yasunori Koide via Wikimedia Commons, Holger Krisp via Wikimedia Commons, and the U.S. Fish and Wildlife Service.

To date, the Asian giant hornet has not been found in Pennsylvania. If you see a very large wasp, you are most likely looking at a cicada killer wasp or a European hornet. Cicada killer sightings increase as annual cicada populations increase in the early summer. They look huge and scary, but they are certainly not murder hornets and are generally harmless if unprovoked. European hornets, also known as giant hornets, are brown-yellow and like other wasps, they will aggressively defend their nests. The verdict: Unless you plan on poking or prodding its nest, if you leave a wasp alone, it'll leave you alone.

Key Takeaways

If a wasp or a bee lands on your food and you want to get it off, don't swat it or make sudden movements (including getting up really quickly). Try to cover up your food, and if you can, trap the bee/wasp under a cup or a bowl and release it after you're done eating.

Charlie Mamlin's message to the Haverford community is that most bees, and honeybees in particular, are actually friendly. "Once they realize you're not a flower, they generally don't want much to do with you, so there's no reason to be afraid of them! Haverford is a home to so many bees, so if you see one on campus, go ahead and say hi and give it a thank you, because that little friend does more to support your life and the things you love than you realize."

October 20, 2021

EMERGING SOLUTIONS TO MICROPLASTIC POLLUTION

Written by Isabel Thornberry and Atira Glenn-Keough

Edited by Lydia Guertin and Anagha Aneesh

From heavy metals to hydrocarbons and oil to plastic debris, marine pollution is a world-wide problem. According to a review by H.S. Auta et al. published in 2017 by Environment International, plastic composes 80-85% of marine litter, and on our current trajectory, the amount of plastic litter in water bodies will only increase. Microplastics don't decompose easily, and with increasing production and few effective clean-up methods currently implemented on a broad scale, we're likely to see more and more microplastics in our environment.

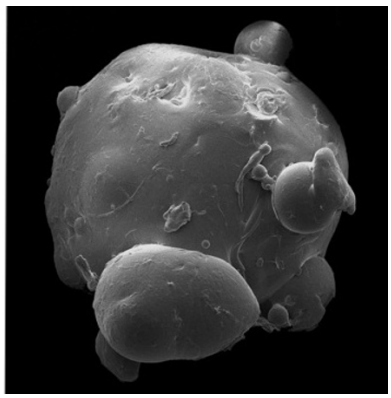
Microplastics are generally classified as either primary or secondary. Primary microplastics are those intentionally manufactured and are often found in face cleaners, toothpastes, and other cosmetics. The use of primary microplastics is becoming increasingly popular in the cosmetics industry, often replacing natural ingredients. Secondary microplastics are those created when larger plastics break down due to environmental factors, such as exposure to sunlight or ocean waves.

Microplastics have a wide variety of detrimental impacts on our environment, as well as directly on ourselves. Not only do microplastics collect in sediment along ocean floors, but they also end up in our food and other biomass. Chemicals leached from these microplastics over time are toxic pollutants that can create imbalances in ecosystems and food webs, destroy habitats, facilitate the spread of invasive species, and harm flora and fauna when absorbed or consumed.

As described in a 2020 review by E. Schmaltz et al., current solutions to reduce marine microplastics entail both prevention and removal techniques. Leading prevention techniques involve installing filters in storm and wastewater drains, some of which are fine enough to catch microplastics as well as macroplastics. Mechanical technologies that skim plastics off of water bodies are being developed as some of the newest removal techniques. Technologies for use in domestic settings are also being developed, such as laundry balls that trap synthetic microfibers, so that microplastics don't reach waterways.

A unique solution to the growing plastic problem is the development of bioplastics, which are defined as either bio-based or biodegradable plastics. Plastics that are engineered to be biodegradable—able to be broken down with the help of microorganisms—are considered a short-term solution to the plastic problem, as there are many problems with biodegradable plastics: they commonly contain harmful additives, are expensive to produce, and require specific collection and composting technologies. The more sustainable bio-based plastics are created out of renewable feedstocks—natural resources that can replenish themselves quickly. These bio-based plastics are a more viable solution to plastic pollution, as they are sustainable and decompose naturally.

Due to the size of microplastics, there are significant limitations on current manual removal techniques. Another proposed solution is biodegradation, which is the use of microorganisms to decompose microplastics. Some microorganisms have been found to use the carbon in plastic as an energy source, and biofilms, which are communities of microorganisms, can already be found naturally occurring on plastic litter. Many microorganisms can adapt quickly to new environments, meaning that biodegradation could be used in a variety of situations to both prevent the introduction of microplastics into marine environments by treating wastewater before it reaches water bodies, and by treating already contaminated environments.



Right: Plastic microbead from a face wash, taken via scanning electron microscopy. Microbeads are used for their exfoliating properties, and they are cheaper than natural alternatives like oats, crushed walnut shells, and sugar. To see if your cosmetic products contain plastic microbeads, check the ingredients list for polyethylene or polypropylene. Image by University of Exeter via Wikimedia Commons, CC-BY-2.0.

November 3, 2021

SEAWEED: A SAVORY SOLUTION TO SAVE THE OCEANS

Written by Catherine Kim

Edited by Narisara Mayer and Marianela Luna-Torrado

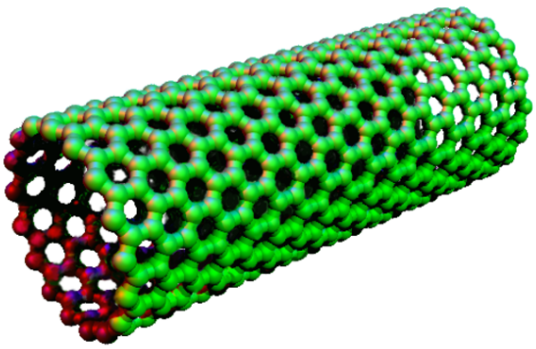
Growing up Korean-American, I ate a lot of seaweed. My mom often made kimbap, vegetables and rice wrapped in seaweed, for me to eat at school. Every year for my birthday, I ate miyeokguk, a seaweed soup. I would have dried and salted strips of seaweed as a midnight snack. Seaweed has always been a huge part of my upbringing and diet, so I did not think much of it and never considered that it would have the potential to save the planet — starting with our oceans.

Over the past decade, our oceans have suffered from eutrophication, a process in which nutrients cause excessive algae growth and kickstart a chain of detrimental environmental effects such as low dissolved oxygen (DO) conditions. Sewage and agricultural runoff like fertilizer and pesticides are appetizing sources of nitrogen and phosphorus that overfeed algae and microbes. As a result, DO decreases to the point of hypoxia where there is less than 2 ml of oxygen per liter of water, leaving sealife gasping for air. When the hypoxic zone expands past its area of origin, anoxia, a total absence of oxygen, is established, and microbes reign supreme, releasing toxic compounds and forming dead zones.

So where does seaweed come in? Seaweed has a knack for getting rid of inorganic nutrients like nitrogen and phosphorus in the water and for increasing DO levels. Thus, scientists have proposed seaweed aquaculture, also known as aquatic farming, to turn the tides in the fight against eutrophication. However, there are some concerns about this solution: sites for seaweed farms may require destroying the habitats they were meant to protect and large scale cultivation necessitates adding artificial, potentially harmful materials to the water. Additionally, transporting seaweed to hypoxic areas could introduce new diseases and invasive species.

Algal bloom resulting from eutrophication. Photo by Lamiot, Creative Commons Attribution-Share Alike 3.0, via Wikimedia Commons.

To improve this proposal, I suggest integrating plant nanobionics, a new field of science aiming to introduce non-native structures and functions to a plant, to transform seaweed farms into monitoring systems. Using spinach as their model, a team of chemical engineers inserted carbon nanotubes — cylindrical molecules made of rolled-up sheets of single-layer carbon atoms that are able to sense a variety of compounds — into spinach plant leaves. When the spinach roots draw in compounds of interest from groundwater, the leaves detect those compounds around ten minutes later, allowing the nanotubes to emit a signal and notify the lab.



Model of a carbon nanotube, which is inserted into spinach leaves to detect chemical compounds. Image by Jorge Stolfi, via Wikimedia Commons.

Though both are green and leafy, spinach is a plant and seaweed is not. Seaweeds are actually protists, but there is still potential for plant nanobionics to be applicable. Seaweeds absorb nutrients from the water through the surface tissues of their "leaves," or, more accurately, their blades, so I propose inserting the carbon nanotubes from the spinach model into seaweed leaves. In doing so, scientists could monitor the nitrogen and phosphorus levels in the water, as the inserted nanotubes would notify them when the seaweeds absorb those nutrients.

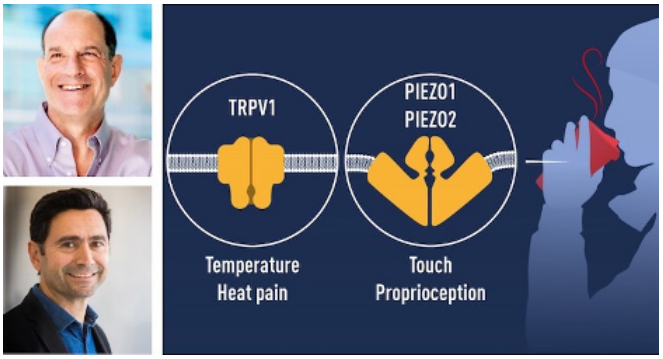
All in all, seaweed is not just delicious, it is also a promising step toward making informed decisions about eliminating eutrophication. Seaweed aquaculture has potential in increasing DO levels in the ocean while monitoring compounds in the water, acting as both a treatment and monitoring solution.

November 6, 2021

NOBEL PRIZE IN MEDICINE AWARDED FOR DISCOVERY OF TEMPERATURE AND TOUCH RECEPTORS

Written by Emi Krishnamurthy

Edited by Kate Braverman and Sooyeon Jung



2021 Nobel Laureates in Physiology or Medicine, David Julius (top) and Ardem Patapoudian (bottom), and the discovered temperature and touch sensing proteins. Images via NobelPrize.org.

This year's Nobel Prize in Physiology or Medicine was awarded to David Julius and Ardem Patapoudian for their discoveries of receptors for temperature and touch, marking a key breakthrough in our understanding of how mechanical stimuli are converted into electrical impulses in the nervous system.

Sight, hearing, touch, smell, and taste, our five major senses, connect our bodies and brains to the world. A sixth sense, proprioception, which helps our body know where it is in space, involves receptors that process sensory information. "Your sensory neurons innervate all the muscles in your body, and from how much your muscles are stretched, you have a very visual — without actually looking — image of where your limbs are," says Patapoudian in an interview with Scientific American earlier this month. "This is how I can close my eyes and touch my nose. This is proprioception." These senses have many different mechanisms — chemical, hormonal — but the mechanism for touch is not completely understood.

In the 1990s, David Julius, working at the University of San Francisco, had discovered a single gene responsible for sensitivity to capsaicin, a chili pepper extract that induces that burning/painful sensation you feel when eating spicy food. Through years of research and millions of gene sequences, Julius and his team were able to identify the gene that encoded a heat-sensing ion channel protein and named it TRPV1.

Ion channels in nerve cells allow ions to flow into the cell and activate an electrical signal. This signal gets passed between other cells and eventually arrives at the central nervous system, where the signal is interpreted as a sensory perception. The ion channel that Julius discovered, TRPV1, only opens at a certain threshold temperature level considered to be "painful."

Ardem Patapoudian's team at Scripps Research in La Jolla, CA identified two genes responsible for mechanosensitivity (sense of touch and proprioception) by using a micropipette to poke variants of a specific line of cells that give off electric signals when poked. The encoded ion channels were named Piezo1 and Piezo2. Although there still remains much research to be done, Piezo2 seems to be involved in a number of functions, including bladder fullness. Additionally, people who lack Piezo2 lack coordination and have limited proprioception, making Piezo2 an exciting possible target for future drugs.

Additionally, both Julius and Patapoudian independently discovered another gene that encodes a protein receptor activated by the cold, which was named TRPM8.

For their years-long work and groundbreaking research on TRPV1, TRPM8, and Piezo receptors, Julius and Patapoudian have been awarded this year's nobel prize in Physiology or Medicine. In order to reach these discoveries, the research teams meticulously deactivated numerous other genes one at a time and noted the functional outcomes of each deactivation. For example, Julius and Patapoudian deleted the TRPM8 gene in mice, and found that those mice couldn't sense cold very well. The process of identifying these genes was painstaking and arduous — it took days to test just one gene candidate, and years to reach a discovery. Additionally, by taking non mechanosensitive cells and inserting the identified genes, researchers could further analyze the role of those genes in mechanosensitivity. Their work has allowed us to better understand how we process temperature and mechanical force information. Future research needs to be done to study the mechanisms of these receptors in a more physiological context so that novel therapies to treat symptoms such as chronic pain can be discovered.

Diversity and the Nobel Prize

The Nobel Prizes in STEM fields have historically represented the benchmark for scientific discoveries around the world. For their groundbreaking contributions to humankind, Nobel Prize Laureates receive over a million dollars in research funding as well as international recognition.

However, it is no secret to most that it has a major diversity problem. This year, all eight Nobel Prize Laureates in Medicine, Physics, Chemistry, and Literature are men. There has never been a Black recipient for Medicine, Physics, or Chemistry. Only 25% of the Nobel Prize in Medicine Selection Committee are women.

A recent episode of Vox's Unexplainable podcast series, "Nobel Prize 2.0," delves into some flaws of the Nobel Prize and how it is awarded. Check it out on Spotify.

November 22, 2021

WHAT DO WE DO WITH E-WASTE? FLASH JOULE HEATING PRESENTS A SOLUTION

Written by Isabel Thornberry and Atira Glenn-Keough

Edited by Kate Braverman and Emily Almgren

With Apple rolling out a new iPhone every year and planned obsolescence encouraging consumers to buy and throw out more and more electronics, electronic waste is piling up in landfills globally. Over 40 million tons of e-waste are produced annually, making it the fastest growing category of solid waste globally. E-waste often includes heavy toxic metals that can leach into the surrounding environment, contaminating soil, water, and food sources. Workers who dispose of e-waste have been found to have higher lead content in their blood because of exposure to dangerous dust and smoke when working with the waste and in the recycling process. Intensive mining practices to recover precious metals found in e-waste further harm the environment by releasing toxic fumes.

Urban mining is a process by which precious metals like gold, silver, rhodium, and palladium are recovered from urban waste. Researchers have been working to develop new urban mining techniques that are more sustainable and efficient in an effort to reclaim precious metals from old electronics and minimize the need for further intensive mining. However, current techniques primarily involve smelting and leaching. Smelting involves melting down metals and can release toxic air pollutants that contaminate much of the surrounding environment. Leaching is the process of treating e-waste with chemicals that turn precious metals into salts that can later be extracted, but this process isn't efficient and often leaves behind large quantities of acidic and toxic residue.

In an article published in early October 2021 in Nature Communications, Ding et al. at Rice University propose flash Joule heating (FJH) as a method to better recover precious metals from e-waste by reducing the energy, time, and money involved in urban mining. FJH was originally used to produce graphene, a usable form of carbon in a honeycomb structure, from food waste and plastics, and applying this technique to e-waste could be a breakthrough in dealing with what is now piling up in landfills. In around one second, electricity raises the temperature of the e-waste to 5,660°F, vaporizing the precious metals and leaving behind heavy toxic metals. The precious metal vapors are then moved into a cold trap, where they are condensed back into solid, refined and purified, and later reused.

FJH as applied to urban mining has proven to have both higher recovery rates of precious metals and lower removal rates of hazardous heavy metals. Over ten times more silver is able to be recovered compared to traditional urban mining methods, and the recovery of other precious metals has also shown significant increase. With FJH, soil once polluted with toxic heavy metals such as mercury, lead, arsenic, and cadmium has returned to safe limits, and some agricultural land can now be reclaimed.

As our world becomes increasingly digitized, e-waste will continue to be a problem that we need to seek solutions for. Finding ways to reduce and reuse waste may be a vital method of combating the climate crisis and preventing further harm to the environment.

December 14, 2021

THE TRAVELING SALESPERSON PROBLEM: IN SEARCH OF POLYNOMIAL TIME

Written by Emily Almgren

Edited by Catherine Kim and Ashley Schefler

Imagine you are planning a road trip. To save time and gas, you want to choose the shortest route that goes through all the cities you want to visit. How do you figure out what path to take? One option is the brute force approach — measuring and comparing the lengths of every possible route to find the shortest one. However, the number of possible paths grows very quickly as you add more destinations. With five cities to visit there are 24 possible routes, but with 22 there are approximately 25 billion billion routes. An algorithm that checks every possible path would be too slow to be useful.

This problem is called the traveling salesperson problem, and it has captivated mathematicians and computer scientists for decades. The goal is to find a general and efficient method for finding the shortest path through a set of points that goes through each point exactly once and returns to the starting point.

The traveling salesperson problem has many varied applications, the most common of which involve transportation logistics such as bus and delivery routes. Planning effective delivery routes has large implications for the profits of companies such as Amazon, which awarded a $100,000 prize in June 2021 to the group that could provide the best machine learning model that learned from and predicted delivery routes taken by drivers. Methods for solving the traveling salesperson problem have also been used in genome sequencing and the production of circuit boards.

Solving the traveling salesperson problem would mean creating a polynomial-time algorithm, a computer algorithm whose execution time is modeled by a polynomial function. As the number of stops increases, the time taken by a polynomial-time algorithm would increase much more slowly than that of the brute force approach, which is an example of a factorial-time algorithm. To date, no polynomial-time algorithm that works for every possible set of points has been found. In fact, Richard Karp proved in 1972 that the traveling salesperson problem belongs to the NP-hard class of problems. This means that no efficient algorithm exists unless the conjecture P=NP is true. This conjecture asserts that problems whose solutions can be verified in polynomial time can also be solved in polynomial time. It is widely believed among computer scientists today that P=NP is false.

The focus of current research is using math to write algorithms that find an approximate solution: a path with a length within a certain percentage of the length of the shortest path. In 1976, Nicos Christofides wrote an algorithm that finds a route that is no more than 50% longer than the shortest route. Christofides's algorithm is fairly simple. It first finds the shortest tree, a network without closed loops, that connects all of the points. In a closed loop all points must have an even number of branches, so to turn the tree into a loop the algorithm connects the points with an odd number of branches to each other in an optimal way. Computer scientists believed at the time that a more accurate algorithm would soon be developed, but that breakthrough did not come for another 44 years.

In 2010, Shayan Oveis Gharan, Amin Saberi, and Mohit Singh began working together to beat Christofides's record. Instead of choosing the shortest tree that connects all of the points, they created a collection of carefully chosen trees and chose a random tree from that set before using Christofides's algorithm to turn the tree into a round trip. In July 2020, Oveis Gharan, Anna Karlin, and Nathan Klien published a paper proving that the new algorithm outperformed Christofides's by 0.2 billionth of a trillionth of a trillionth of a percent. This improvement is incredibly small, but it breathed new life into the search for a more accurate algorithm because it showed that improving Christofides's algorithm is possible.

When you're planning your next road trip, you may never have a polynomial-time algorithm to find the shortest route, but researchers have come a long way at finding solutions to the traveling salesperson problem. These new understandings of the problem have profound implications: they shed light on related optimization problems and are useful for a wide array of applications.

January 26, 2021

PARTHENOGENESIS: VIRGIN BIRTHS PROVIDE HOPE FOR THE ENDANGERED CALIFORNIA CONDOR

Written by Isabel Thornberry

Edited by Justin Adler and Emi Krishnamurthy

Parthenogenesis is a form of asexual reproduction whereby females eggs develop into embryos without fertilization from a male. While this phenomenon is commonly observed in fish, reptiles, and plants, it is rare or unknown in birds such as the California condor.

As part of the captive breeding program of California condors, Oliver Ryder and his team developed a genetic database for all California condors such that breeding programs can work to maintain genetic variation in condor populations and prevent inbreeding, as described in an article published in October in Oxford Academic's Journal of Heredity. Ryder and his team reviewed the genetic data of 911 California condors born in the captive breeding program. The team found two instances of parthenogenesis, one in 2001 and another in 2009. This is the first time reproduction of this kind has been observed in California condors.

California condors, like most animals, are diploid, meaning that they have two copies of each of their chromosomes, one inherited from the egg and the other from the sperm. In the case of parthenogenesis, there is no male to provide half of the child's chromosomes, so both sets of genetic material come from the mother. It was this fact that led researchers to discover the cases of parthenogenesis: all 21 of the genetic markers compared were the same on both copies of the chromosomes. Researchers could identify a mother, but not a father.

Both offspring were male, which also supports the occurrence of parthenogenesis because this is the only viable combination of sex chromosomes that could both come only from a mother. An individual's sex is determined by their combination of sex chromosomes, and for bird species such as California condors, males have ZZ sex chromosomes, and females have ZW. Thus, female eggs will either contain a Z or W chromosome, and the offspring from parthenogenesis will be either ZZ or WW. The Z chromosome contains necessary genes, so all viable offspring from parthenogenesis will be ZZ and therefore male.

California Condor. Photo by Chuck Szmurlo, CC BY 3.0, via Wikimedia Commons.

These instances of parthenogenesis in California condors were unusual because they were in a captive breeding program, meaning that males were present with the females. In previous cases, parthenogenesis is known to occur only when a female cannot find a male to mate with. This may be because offspring resulting from parthenogenesis (parthenotes) do not have as much genetic variation as offspring resulting from sexual reproduction, and it is more likely that unfavorable traits may be passed down. However, while the two parthenotes both died at fairly young ages of 1.9 and 7.9 years old, their deaths weren't explicitly related to parthenogenesis and their lack of genetic diversity.

More research is needed to determine if parthenotes can reproduce themselves and how parthenogenesis may factor into the genetic diversity and range expansion for California condors. However, pathogenesis could be beneficial for California condors in the long term.

January 30, 2021

RESEARCHERS EXPRESS CONCERNS ABOUT PERSONALITY TESTING IN WORKPLACE TRAINING

Written by Andreas Wingert

Edited by Emi Krishnamurthy and Zoe Frazer-Klotz

Personality Test Cartoon. Photo via breakthroughvisuals.com

While personality tests in the workplace setting were originally used for personnel selection, human research departments (HRDs) have increasingly employed personality tests in workplace training despite the paucity of evidence supporting their use for this purpose.

Several concerns about the use of personality testing in workplace training were identified in a 2017 study by Lundgren et al., who analyzed multiple case studies. Using data collected in Germany, the United Kingdom and the Netherlands between 2012 and 2016, the researchers reviewed interviews, test reports, product flyers and email correspondence from publishers, associations, psychologists and HRD practitioners.

Lundgren et al. found a lack of collaboration between HRD practitioners and psychologists with respect to the use of personality tests in workplace training. For example, when selecting which personality test(s) to use, psychologists emphasize the importance of psychometric properties such as validity and reliability, while HRD practitioners often prioritize other parameters, such as cost, perceived ease of use, or historical precedent (i.e., use of whatever tests have been used by the organization in the past even if those tests are suboptimal to achieve the organization's current intended purpose). Furthermore, the researchers found that psychologists generally believe personality tests should be selected and administered by trained psychologists, while HRD practitioners typically regard personality test selection and administration as part of their skill set.

This lack of collaboration between HRD practitioners and psychologists with respect to the use of personality testing in workplace training, and since membership to most national psychological associations is not available to HRD practitioners, the latter often rely on test publishers and marketers for access to personality tests and for information regarding which test(s) to use and best practices with respect to test administration. This, in turn, strengthens the influence of commercial, rather than scientific, factors on HRD practitioners and their use of personality testing in workplace training.

The researchers also found that both HRD practitioners and employees, perhaps due to such factors as expediency and lack of expertise with regards to the appropriate use and interpretation of personality tests, may use personality tests in the workplace to categorize employees. This may lead to employees being pigeonholed, inhibiting effective workplace training.

A related concern is how test feedback is used. In order to facilitate effective training and development, it is important that test feedback not be perceived as an end, but rather as a starting point. The latter may be undermined if employees are pigeonholed by their test results.

Another concern identified with respect to the use of personality testing in workplace training is that of data privacy. While there are strict rules that govern confidentiality in academic research and in psychometric testing conducted by licensed mental health workers, HRDs may not be aware of, and adhere to, these standards. Questions such as who receives test feedback and how results are stored involve important ethical and legal considerations.

In sum, the researchers concluded that while decisions regarding personality testing in workplace training are generally initiated and made by HRD practitioners who hold the budget for such training, there is typically little scientific oversight for the use of such tests in the workplace. Bridging the gap between psychologists and HRD practitioners, and combining scientific evidence with practical application, would help to optimize the use of personality testing in workplace training and to measure its impact on organizational outcomes.

February 9, 2022

DINNER IN THE WOODS: A CATALOG OF EDIBLE FUNGI ON HAVERFORD'S CAMPUS

Amanita muscaria (also known as "Fly Agaric"), a beautiful mushroom with a rich history. Image taken in the Haverford Pinetum. Note: All images featured in this article were taken by Oscar Garrett.

Written by Oscar Garrett

Edited by Justin Adler and Ashley Schefler

Disclaimer: Foraging is a fun hobby with tasty rewards, but it can result in injury or death with the right combination of ignorance and misfortune. Do not eat anything you find without being 100 percent sure of its identity. The contents of this article are intended to educate you of these fungi's presence on campus, not identify them. Consult a field guide or foraging expert before consuming any wild edibles.

When you enter the strange yet magnificent world of fungi, you will never look at the forest floor the same. Indeed, you'll be looking at it a whole lot more. Fungi are a very diverse kingdom, ranging from single-cellular yeast (which we use in fermentation) to the largest organism on earth (a giant honey mushroom colony in Oregon). Multicellular fungi can be filamentous, composed of tube-like cells called hyphae. These hyphae form a network called mycelium which constitutes the vast majority of the fungi's body mass. Some of these fungi will produce a fruiting body, called a mushroom, which acts to spread the fungi's spores.

There are hundreds of thousands of characterized mushrooms, and they are extremely diverse in their shapes, sizes, and biochemistry. Humans have been utilizing mushroom biochemistry for millennia. Indeed, the iceman (the mummified remains discovered in the Ötztal Alps dated to have lived about 5000 years ago) was found with Chaga and birch polypore for their fire starting and medicinal properties, respectively. Fungal biochemistry continues to be used extensively today, both in medicine and the culinary arts. Today, we are going to be learning about a few of these mushrooms, ones that can be found on Haverford's campus!

Each of these mushrooms are species I have personally found, and a few I have eaten. I do not recommend eating any foraged mushroom you are not 100 percent sure of. That being said, many of these look quite unlike any toxic mushrooms and are relatively safe to identify for amateurs provided the proper steps are taken. For those steps, please consult a mushroom foraging field guide.

Hen of the woods

Hen of the woods, aka maitake, is a parasitic polypore mushroom often found at the base of maples, elms, and most often oaks. With their dull brown color, they can look like a small pile of dead leaves. The "leaves" of the mushroom are arranged in a rosette, connecting to the base of the tree at a single point. The undersides of the caps have white pores, small visible holes from which spores are released. These are in season during the fall, from late August to early November. On campus, they are quite common at the base of oak trees, especially those near Founders and along the main entrance. They are commonly around 2 or 3 pounds, but can get quite large.

I have eaten this one and can personally attest to its deliciousness. The fronds can be quite dirty so take care in cleaning them. They do great in small, thin slices marinated and grilled.

Chicken of the woods

Once you know chicken of the woods, it is unmistakable. Bright orange and yellow, it sticks out like a flame on dead and living wood. It too has pores on the undersides of its brackets. It can most commonly be found from July through October. Truly a beautiful mushroom, and delicious too! It has the consistency of tofu when cooked and can be used similarly. When harvesting for consumption, look for the younger mushrooms since they can get tough as they age.

Enoki

If you have ever been to an Asian grocery store or are familiar with Asian cooking, you'll know a common mushroom to use is enoki. Enoki is quite peculiar because in the wild, it looks very different from what you can buy in stores because store-bought enoki is farmed and not exposed to light. Wild enoki has a sticky red, orange, or brown cap with gills (gills are thin, paper-like structures on the underside of the cap which release spores). Enoki can commonly be found on dead logs. These mushrooms prefer cold weather, so they can be found in late fall or early spring. This is a mushroom to be careful foraging, however, as it has a poisonous look-a-like: the Deadly Galerina.

Oyster

Oyster mushrooms are a very popular mushroom and often are some of the first foraged by beginners. They come in several colors, though the most common in this area is a grayish white. Their gills are quite unique, with the gills gradually merging with the stipe (the "stem") of the mushrooms. These mushrooms sprout from dead trees; you can often find them on the large standing stumps along the nature trail. Their season is quite wide, ranging from midsummer to early winter. Additionally, these mushrooms are super easy to cultivate at home. You can purchase mushroom growing kits online which come with a block of straw already fully colonized with white, fuzzy mycelium, or you can grow your own from scratch with a little starting of mycelium and some organic waste like cardboard or coffee.

Oyster mushrooms have a firm consistency when cooked, almost like octopus or shellfish, though it changes depending on the age of the mushroom. They work well as meat substitutes and are great just sauteed with onion, garlic, and butter.

Honey mushrooms

Honey mushroom is a name given to several species of mushroom, so specifically, I will be discussing Armillaria ostoyae. The cap of the mushrooms is variable, but often brown with small dark brown hairs concentrated at the center. They have a ring on their stipe and a white spore print (spore prints are determined by placing the cap face down on a non-white flat surface for a few hours under a glass to allow the spores to fall on the surface). They often grow in clusters and can be very prolific. Honey mushrooms can be found on dead or dying trees (or from the ground on buried wood) in the fall, with their peak in October. Important note: there is a deadly look-a-like to this mushroom. The Deadly Galerina looks similar and grows in similar locations, but they can be easily distinguished by their rusty brown spore print.

I personally have not tried these before, but I have heard they are delicious and are prized in Europe. If it's your first time trying them, eat a small amount at first since some may experience gastrointestinal distress after eating this mushroom. Unfortunately, the name "honey" mushroom refers to their color, not their taste, but some say they do have a sweet finish.

Blewit

Blewits have variable color but can be found in a strikingly beautiful lavender or a purplish white. They have a smooth cap, tightly packed gills, and a bare stipe. Blewits have a pink spore print, which can be used to distinguish them from some poisonous look-alikes. They can often be found growing in wood chips during the fall through early winter.

This is another mushroom I have not personally tried, but again, it is more commonly consumed in Europe. It is considered a choice edible, but they are known to cause allergic reactions in some individuals. Like with honey mushrooms, it is advised to consume only a small quantity at first.

Chicken fat mushroom

Chicken fat mushrooms are bright yellow in color with a sticky, slimy cap. They are a type of bolete, which means they have pores on their underside despite having a stipe and cap. It has a brown spore print. These mushrooms can be found in late summer through fall, often near pine trees with which they have a mycorrhizal (symbiotic) association.

I have not tried these mushrooms, and with their texture, I do not plan on it either. Some say they are underrated and compare its strong taste to organ meats. These mushrooms should be handled with care since some individuals can have skin reactions to the slime.

These are just the tip of the iceberg when it comes to fungal diversity on campus. There are many other interesting mushrooms like medicinal Reishi and Turkey Tail, deadly Death Cap, or psychoactive Fly Agaric. I hope this article has sparked an interest in foraging, and at the very least, encourages you to look and think critically about the funny-looking masses sprouting from trees and dirt.

Further learning

If you'd like to learn more about fungi, the following are some of the media I have learned from.

For mushroom identification: iNaturalist (app), Field Guide to Wild Mushrooms of Pennsylvania and the Mid-Atlantic (book), Learn your Land (YouTube channel).

For interesting facts about mushrooms: Any of Paul Stamets' books or episodes of podcasts on which he has been a guest, Entangled Life by Merlin Sheldrake (book), StoneAgeMan (YouTube channel), Fantastic Fungi (documentary).

February 23, 2022

THE COLORADO WILDFIRES: HOW CLIMATE CHANGE IS CHANGING WILDFIRES

Written by Celeste Cubbage

Edited by Ashley Schefler and Anagha Aneesh

2020 Colorado Wildfire. Photo by Malachi Brooks, via Unsplash.

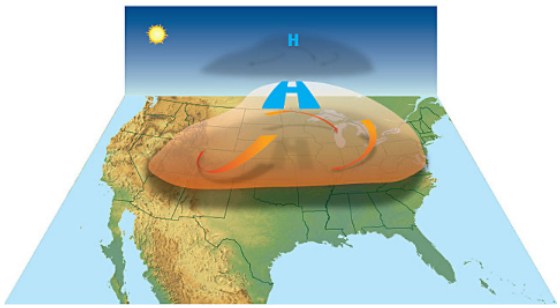
In 2022, as of early February, there have already been 2,388 fires that have burned a total of 40,822 acres across the U.S., surpassing a 10-year average of 1,924 fires and 38,501 acres, according to the National Interagency Fire Center. In 2021, the state of California faced unprecedented fires that raged throughout the year, burning a total of 2.5 million acres and changing officials' definition of the "fire season" to a "fire year."

One of the most recent catastrophic wildfires occurred on December 30th of last year, when a suburban neighborhood in Boulder County, Colorado experienced one of the state's worst fires in history. This wildfire was shocking to the area, which had just had snow storms a few weeks earlier. The event burned about 6,200 acres, caused at least one confirmed death, and destroyed almost 1,100 homes, prompting over 35,000 people to evacuate the community and surrounding areas. Many believe the fire was able to start and spread so quickly due a severe drought in the area that had lasted through the summer into December.

Catastrophic wildfires require a combination of environmental conditions including high temperatures, low humidity, decreased rainfall, dried flora, and fast wind speeds, as explained by Kasha Patel for the Washington Post. In the example of the December fire, a combination of dangerous weather conditions from the recent drought, heatwave, and high wind speeds made the wildfire so deadly and devastating for the Colorado community. A report from the National Weather Service on that day showed severe winds up to 100 mph fanned the wildfire out into its surroundings and increased damage to already devastated homes and businesses.

While meeting these exact natural requirements may seem infrequent, rising global temperatures are actually creating the perfect environment for wildfires in many parts of the country.

As heat waves become longer and more intense due to greenhouse gasses trapping heat in the atmosphere, forests and vegetation begin to dry out. From this, two main problems occur. First, as postdoctoral researcher at the Lamont-Doherty Earth Observatory at Columbia University Jane Wilson Baldwin explains, a feedback loop is caused when dried land is unable to cool itself through evaporation and makes the surface even hotter.



Formation of a heat wave. Photo by U. S. National Weather Service/ National Ocean Service.

Since a heat wave is a high-pressure system that traps air in one place as it warms, the air in that bubble becomes hotter and hotter over time with the added effect of ground heating. These dried out environments will become even more susceptible to fires if extreme heats reduce the moisture in the vegetation to less than 30%, creating a perfect ignition fuel. Hot areas with ample dried out plant life become the exact geography where wildfires thrive. All it takes at that point could be one small accidental spark for another devastating fire to begin.

The Colorado Wildfire ended a year full of climate disasters, with Nina Lakhani, a climate justice reporter for The Guardian, reporting in January that at least 650 people died in the United States in 2021 from various natural disasters such as heatwaves, hurricanes, wildfires and flooding. In order to avoid these natural disasters from devastating our communities, it is critical to remember that the true problem comes directly from the global climate crisis.

February 3, 2022

HOW DO SNAKES MOVE?

A QUIRKY QUERY

Quirky Queries answers your random science questions

Written by Emi Krishnamurthy

Edited by Catherine Kim and Anagha Aneesh

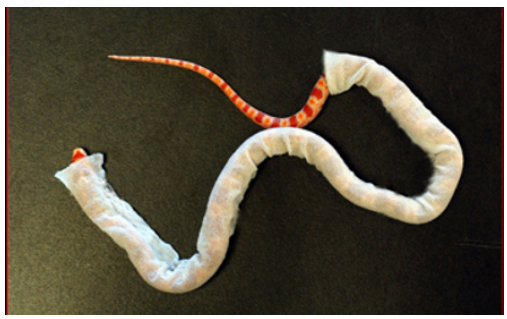
How do these legless creatures slither, glide, crawl, and climb? Here we discuss multiple different mechanisms of snake locomotion (including flying!).

Serpentine locomotion

Snakes are known to slither. They move by pushing off of rocks, branches, and other surfaces in order to propel forward, but how do snakes travel on flat surfaces? Slithering, called serpentine locomotion, is dependent on the muscles that connect a snake's skin, spine, and hundreds of ribs and contract to form that familiar S shape.

Snakes use friction with small bumps or uneven surfaces on the ground in order to propel forward. Their scales have hard and polished surfaces, and are layered such that their jagged edges are only exposed in one direction. This directionality means that the friction exists in a single direction, so they can use this resistance to propel forward (but not so effectively backward). For instance, a snake wearing a sock jacket can't move as effectively as without — even though the friction on the surface of the snake is high, it is equal in all directions, so the snake just wiggles around in place.

As a snake forms an S shape, the scales running perpendicular to their direction of travel (the middle of the "S") have more friction with the ground; this segmented resistance is key for serpentine locomotion.



Corn snake wearing a cloth jacket for an experiment by David Hu at the Georgia Institute of Technology (2018).

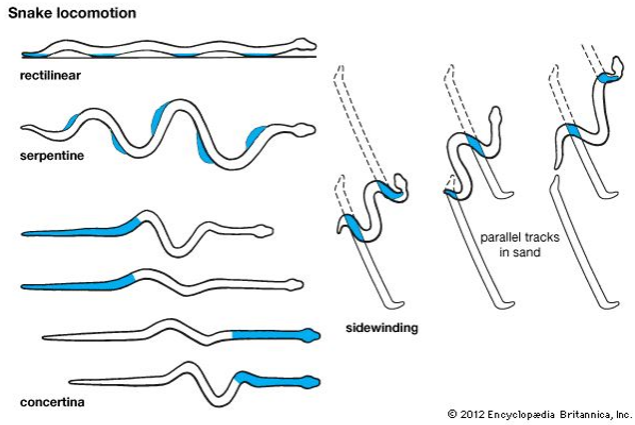
Although almost all snakes can utilize serpentine locomotion, there are several other ways snakes can move. One such mechanism is "concertina" (as in "accordion") locomotion, which resembles a sideways inchworm. Snakes anchor the front of their bodies to a surface, scrunch up the middle of their bodies, then anchor the back, release the front, push forward, and then repeat.

Rectilinear Locomotion

Rectilinear locomotion is characterized by a slow scoot forward in a straight line. Rectilinear motion depends on a wave-like flow of belly muscle contractions that pull and release the snake's skin (it looks pretty creepy — find a video here).

Discovered in 2018, rectilinear locomotion is more common in larger snakes like boas, and it is especially prevalent in tunneling snakes — which makes sense, as rectilinear locomotion takes up virtually no lateral space.

Sidewinding Locomotion



Snake locomotion. The areas shaded in blue represent the points of the snake's body in contact with the ground at a given moment. Via the Dickinson County Conservation Board.

Sidewinding is another locomotive mechanism, in which snakes move sideways along smooth surfaces. Out of all locomotive mechanisms discussed so far, sidewinding depends the least on surface friction. Sidewinding involves minimal contact between the snake's body and the ground, with only two points of contact on the ground at a time (sort of similar to walking). If we think of the snake as an S shape, the middle and top of the S are on the ground, and the two curved sections are raised. Sidewinding snakes leave behind unique J-shaped, parallel "foot"-prints reflecting their sideways movement.

It seems really counterproductive, but sidewinding allows snakes to move extremely fast without sliding — on surfaces without much friction. Sidewinding locomotion is mainly used by desert/sand snakes, such as the sidewinder rattlesnake (also called the horned rattlesnake), which can travel up to 18 miles per hour! (video)

Bonus: Flying?

This video is a beautiful example of a snake that uses rectilinear locomotion to climb up trees, and as it leaps off of branches, it widens its body and glides through the air!

Most snakes are capable of more than one type of locomotion — certain snakes might use rectilinear locomotion when relaxed, but may slither in a serpentine locomotion if trying to flee quickly.

Studying these mechanisms is not only interesting, because snakes are cool and beautiful, but it also has applications in ro-

bots and technology. Robots that use these locomotive techniques, evolved over millions of years, may have applications in medicine, nanotechnology, search-and-rescue missions, archeological digs, and much more.

Here is a cool example of a modular robot utilizing rectilinear locomotion; each segment of the chassis is contracting in a wave pattern. This modular robot has a rounded body and moves similar to sidewinding; it also can rotate freely and move laterally!

HOW DO FIREFLIES GLOW?

A QUIRKY QUERY

Firefly. Photo by @yb_woodstock on Flickr, cc-by-sa-2.0, via Wikimedia Commons.

Written by Sarah McNamara

Edited by Emi Krishnamurthy and Ashley Schefler

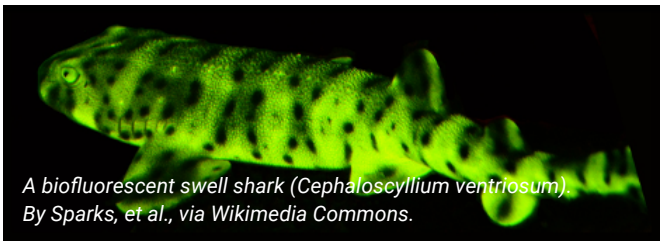
Fireflies are winged beetles, and there are over 2000 species distributed across the temperate and tropical areas of the world; in fact, especially when considering that not all species glow, it is likely that there are multiple species within your own backyard alone!

Fireflies are bioluminescent, meaning they produce and emit light through chemical reactions in their bodies. Light is produced in a firefly's abdomen — the "light organ" — when oxygen, calcium, ATP (an important energy source), and the chemical luciferin combine in the presence of a bioluminescent enzyme that facilitates and speeds up the reaction. The light that is produced is "cold light," and therefore differs from that produced by a light bulb, for example. While a light bulb gives off light and heat simultaneously, fireflies lose relatively negligible energy as heat, and thankfully so! One can imagine that it's not too pleasant — or viable, in this instance — having an organ that is as hot as a light bulb…

But here is another fascinating question: how do fireflies control the flickering of their light? The answer, in short, is oxygen! Every chemical essential to light production, except oxygen, is already present and available in the beetle's abdomen; this means that oxygen availability dictates whether the firefly's light is on or off! Oxygen transfer, however, happens relatively slowly — slower than the rate at which fireflies flicker; so it turns out that there is another key player involved: nitric oxide (NO) gas.

Nitric oxide acts as a "mediator," influencing the accessibility of oxygen within the light organ. Even when oxygen is present in the abdomen, in the absence of NO, it is bound to the mitochondria's surface, thus unable to participate in the light production reaction. Conversely, if there is nitric oxide, the gas can bind to the mitochondria in oxygen's place, freeing oxygen to combine with the other chemicals for bioluminescence until all the NO has been broken down. Interestingly, if fireflies are exposed to high concentrations of nitric oxide in a closed container, they will even glow nonstop!

Fireflies, of course, are not the only bioluminescent organisms. In fact, it is estimated that up to 90% of deep-sea creatures demonstrate some degree of bioluminescence, including certain sharks.



A biofluorescent swell shark (Cephaloscyllium ventriosum). By Sparks, et al., via Wikimedia Commons.

But because lightning bugs are the focus of this article, let's conclude with some lightning-fast fun facts about them:

- Bioluminescent fireflies evolved from pheromone-only fireflies, in which pheromones, rather than patterns of light-flashing, were sexual signals.
- The wingless females of the Lamprigera firefly are huge– they can even be the size of your palm!
- It is uncommon for predators to eat fireflies, as they produce defensive steroids that make them distasteful; but if a certain frog doesn't mind the taste and eats enough fireflies anyways, it, too, will begin to glow!
- The firefly species Photuris frontalis is unable to produce the aforementioned defensive chemicals, called lucibufagins. As a result, once females of this species have mated, they begin to copy the flashes of another species and attract a different population of males. To the males' surprise, upon arrival, they do not mate with the females– they are instead eaten by them. This allows the mothers to acquire and utilize the males' natural lucibufagins for increased protection for themselves and their eggs.
- The majority of a firefly's life cycle is spent in the larval stage as it preys on animals in soil and leaves. Destruction of its habitat and artificial light pollution, then, are especially significant threats during a firefly's youth, and it could ultimately lead to the extinction of species.

March 18, 2022

HOW DOES WIND HAPPEN?

A QUIRKY QUERY

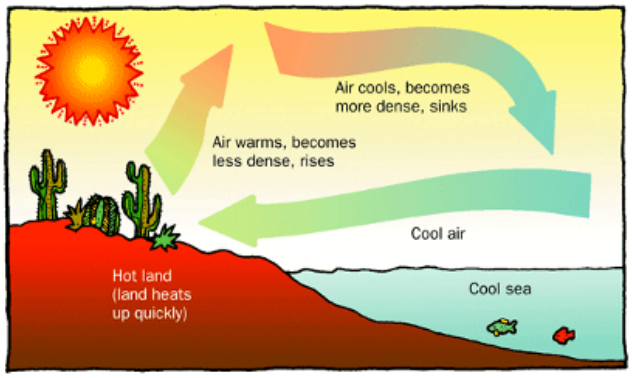
Written by Simon Thill

Edited by Emi Krishnamurthy and Ashley Schefler

Hurricane Katrina. Courtesy of NOAA

This is an excellent question, and one that I was curious about myself when I was younger. I would often ask my parents scientific questions, and they would do their best to respond, sometimes without actually knowing the correct answer. When I asked this same question, my parents told me something along the lines of "wind is caused by the rotation of the Earth." While the Earth's rotation does play a significant role in wind and weather patterns, this is not the complete answer.

You may have heard that hot air rises and cool air sinks. This is because air expands as it is heated, so it is less dense than cool air. This is an important phenomenon because the sun does not heat the surface of the Earth equally — air near the equator is significantly hotter than air near the poles, for example. Heated air expands, rises, and creates an area of low pressure, as explained by National Geographic. Conversely, cold air contracts, sinks, and creates areas of high pressure. Air will flow from areas of high to low pressure, causing wind. The greater the difference in pressure, the faster the air will flow, and the stronger the wind will be.



"Properties of Matter Reading Selection: Density Creates Currents."

The rotation of the Earth does affect the wind, but it does not cause it. If the Earth were stationary, air would flow directly from areas of high to low pressure. As it so happens, the Earth is not stationary — it rotates around its axis. Earth's rotation means that wind that would normally follow a straight path is deflected: clockwise in the northern hemisphere and counterclockwise in the southern. This creates what's called the Coriolis effect. This complicated phenomenon is the cause of many weather patterns, including hurricanes and tornadoes.

April 4, 2022

DON'T LOOK UP: A SCIENTIFIC REVIEW

Written by Kate Braverman

Edited by Ashley Schefler and Anagha Aneesh

*** Warning: spoilers ahead!**

Don't Look Up, a film released on Netflix in December 2021, provided a metaphorized take on the relationship between the scientific community, the political sphere, and the public in regard to climate change. In a fictionalized United States, Dr. Randall Mindy (Leonardo DiCaprio), an astronomer at Michigan State University, and his PhD student, Kate Dibiasky (Jennifer Lawrence), try to warn the public about a comet, first discovered by Dibiasky, scheduled to collide with the Earth in six months. Encountering the ineffectual POTUS Orlean (Meryl Streep) anda CEO tech billionaire, Peter Isherwell (Mark Rylance), only concerned with making a profit, Mindy and Dibiasky fail to prevent the comet from striking the Earth, ending in an apocalyptic collision that kills nearly all life on the planet. Lacking a hopeful statement on the future of the fight against climate change, the film primarily attempts to show the frustrations and fight of the scientific community against political and economic inaction.

The film features an unsuccessful attempt to blow up the comet into smaller, retrievable pieces by un-peer-reviewed drone technology. How realistic is the drone technology? And what is so important about peer review?

Upon discovering that the comet has rare-earth elements worth trillions of dollars, Peter Isherwell, a CEO of a technology company, proposes a plan to President Orlean that involves the use of many small drones to attach to the comet and blow it up into smaller, retrievable pieces that will land in the ocean. The plan seems ambitious and futuristic, but NASA has recently undergone a test project to determine the plausibility of using similar drone technology to crash into an asteroid to divert its course. Similar to *Don't Look Up*, the goal of the project is to determine if it would be successful for a "hazardous asteroid" headed towards Earth. The mission, called the Double Asteroid Redirection Test, or DART, was launched in November 2021. The DART spacecraft isn't expected to collide with the asteroid, which is non-threatening to Earth, until late September or early October 2022. The spacecraft will collide

Still from "Don't Look Up" (Adam McKay, 2021)

with the asteroid with a speed of approximately 14,764 mph. The impact that the spacecraft will have on the orbit of the asteroid will be measured by telescopes on Earth, informing NASA scientists on the potential future success of the method against an Earth-bound asteroid.

Blinded by the profits associated with the drone tests in *Don't Look Up*, the president relies on an un-peer-reviewed project for the survival of human-kind. The drones ultimately fail and human life on Earth essentially ends. In real life, the consequences of un-peer-reviewed studies and articles aren't so drastic, but peer review is nonetheless an essential part of the scientific process.

Peer review serves two functions, according to a 2014 paper published in the Journal of the International Federation of Clinical Chemistry and Laboratory Science. Peer review is the process in which an author's scholarly work is reviewed by other experts in the field before publication. It firstly ensures that the research itself is high-quality, accurate, properly executed, and original, key aspects of a scholarly paper that help to validate its findings. Secondly, peer review improves the quality, in terms of readability and clarity, of the paper itself. In its second use, peer review allows for an additional editing of the paper prior to its publication.

The lack of peer review most likely wouldn't cause the Earth to blow up like in *Don't Look Up*, but it does help to prevent misinformation from poorly conducted and edited scholarly articles from permeating in the scientific community and among popular audiences. For audiences across the world, Don't Look Up also provides a better understanding of the importance of relying on scientific merit while addressing issues with worldwide repercussions.

April 4, 2022

THE EXTRAORDINARY AND DISASTROUS ERUPTION OF THE HUNGA TONGA-HUNGA HA'APAI VOLCANO

Written by Ashley Schefler

Edited by Sarah McNamara and Anagha Aneesh

On January 15, 2022, the largest volcanic eruption in decades devastated the island nation of Tonga in the South Pacific Ocean. The blast released a massive amount of energy, equivalent to between 4 and 18 megatons of TNT, which is hundreds of times more powerful than the nuclear bomb dropped on Hiroshima.

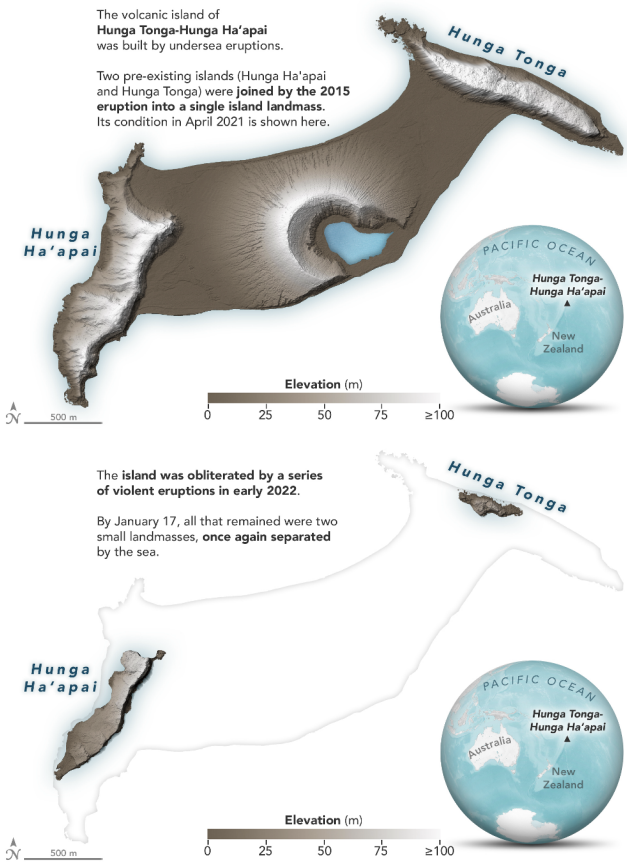
The explosion created a low-frequency pressure wave that circled the Earth, causing the entire atmosphere to oscillate. Ash has coated the islands, causing a serious shortage of clean drinking water, and a tsunami caused by the eruption wrought widespread damage. The effect on local agriculture is of particular concern, with ash covering crops, saltwater flooding the area, and acid rain a potential threat. The disaster also broke the nation's only undersea cable, disconnecting most residents from contact with the outside world.

The volcano has been very active in recent years. In fact, the island on which it sat did not exist until 2015, when the volcano ejected enough material to connect the islands of Hunga Tonga and Hunga Ha'apai into one larger landmass. The volcano is huge, with a width of 12 miles and a height of 1.1 miles from the bottom of the sea floor. The newly created island represents just one section of its 3-mile-wide caldera — the bowl-shaped hollow formed at the center of a volcano by eruption-triggered collapse — sticking out of the water. However, the volcano's recent eruption completely obliterated this new landform, tearing the two islands apart again and leaving shrunken versions of their former shapes in the wake of its destruction.

In the weeks leading up to the massive January 15th eruption, there were several smaller Surtseyan eruptions, meaning they involve the violently explosive interaction between cold water and incredibly hot rising magma. However, most Surtseyan eruptions, such as those witnessed in the early weeks of 2022, involve only small amounts of water and magma coming into contact, and could not have caused the scale of eruption seen on January 15th.

NASA scientist Jim Garvin has hypothesized that some weakness in the rock structure of the volcano must have enabled a significant enough collapse for a massive amount of water to come into contact with the magma all at once, causing the huge explosion. Dr. Garvin's team has been studying this volcano for years. They have been able to map the rapidly changing landscape in great detail using a combination of observations from a commercial satellite company, the Canadian Space Agency's RADARSAT Constellation Mission, NASA's ICESat-2 mission, and the Schmidt Ocean Institute. RADARSAT and ICESat-2 are both used to make altitude measurements, an area of study called altimetry; RADARSAT uses radio waves to do this, while ICESat-2 uses lasers. The Schmidt Ocean Institute uses sonar—underwater measurements utilizing sound waves—to produce bathymetry data. Bathymetry is the underwater version of altimetry; it refers specifically to the measurement of depth in a body of water.

Garvin's team believes that the same island-forming volcanic processes that shaped the landscape of Hunga Tonga-Hunga Ha'apai may have taken place on a water-covered Mars 2-3 billion years ago. Studying these processes on Earth can thus help Garvin's team make conclusions about the formation of similar landforms observed on Mars.



These figures from the NASA Earth Observatory show how the Hunga Tonga-Hunga Ha'apai Volcano dramatically shaped and reshaped the landscape, joining two islands and then tearing them apart again.

April 20, 2022

MARKING THE PASSAGE OF TIME: SPRING 2022 STARGAZING

Written by Karen Masters, Professor of Astronomy and Physics at Haverford College

Edited by Emi Krishnamurthy

While it may feel like we're stuck in a repeating loop of Spring 2020, watching the night skies can remind us that the seasons do actually keep passing by. Indeed, many cultures throughout history have used the night skies to mark the passing of time. In my home country of England, ancient peoples built Stonehenge, probably to track the motion of the Sun (the brightest star in the sky!) and mark the year. In New Zealand, the Maori used the first sighting of Matariki (also known as the Pleiades) to set the start of the new year. The hottest part of late summer in the Northern hemisphere is termed the "dog days of summer" because the Sun is in the same part of the sky as the "dog star," Sirius.

For me, the most obvious change in the night skies has always been the annual appearance and disappearance of Orion. In the early part of the spring semester, this iconic constellation has had center stage in the sky, rising in the Southeast at dusk and traveling across the southern skies to the west as the Earth turns in its daily motion. By the end of the semester, however, it will disappear into the sunset and be invisible for another year.

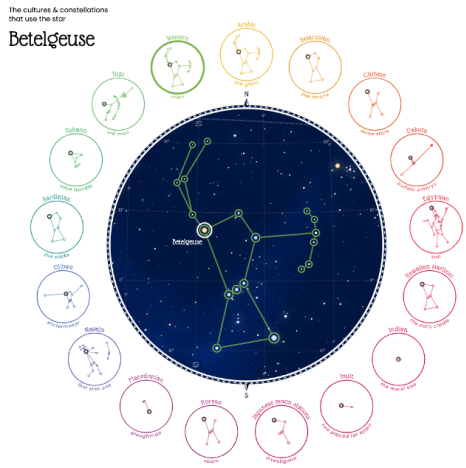
Orion is one of my favorite constellations, partly because it is one of the easiest to pick out in the sky, but also because includes two of the brightest stars in the skies: Betelgeuse, the redder star at the upper-left of the constellation, and Rigel, the blue supergiant at lower-right. Students in my classes know I like to use this pair (along with the binary stars Alberio, which you can only see through a telescope) as an example of how they can see for themselves that stars have different colors, set by their surface temperature. While our eyes are not good at seeing color at low light levels, sometimes we can pick out a faint hue, like in the reddish color of Betelgeuse, which in contrast to the bluish white-hot supergiant Rigel is a relatively cool red supergiant star.

Every human on Earth looks up at the same skies, although their perspective depends a little bit on exactly when and where they are. I remember visiting the Southern Hemisphere once and being pleasantly surprised to see Orion inverted relative to how I had been used to seeing it. It makes complete sense once you think about it, since we don't live on a flat Earth, our perspective relative to the skies changes significantly when we move in latitude (towards or away from the Equator).

Orion through the dome opening of the 12" telescope at Strawbridge Observatory. Feb 5th 2022. Credit: Karen Masters

Of course, the constellations we name in astronomy are entirely human inventions, a giant dot-to-dot puzzle in the skies. We now know that the bright stars that ancient Greek astronomers joined together into the constellation Orion, vary from 245 to over 1300 light years away from us, not physically connected at all, apart from all being in the same Galaxy as the Sun! To explore how various different cultures have drawn different patterns in the night skies you might like to visit Figures in the Sky, which is a beautiful example of artistic data visualization. And if you prefer just to look up at the skies you can enjoy stargazing and inventing your own patterns.

Happy Stargazing, and keep looking up.



A screenshot from Figures in the Sky, by Nadieh Bremer.

April 13, 2022

WHAT ACTUALLY HAPPENS WHEN YOU BLACK OUT FROM DRINKING?

A QUIRKY QUERY

Written by Simon Thill

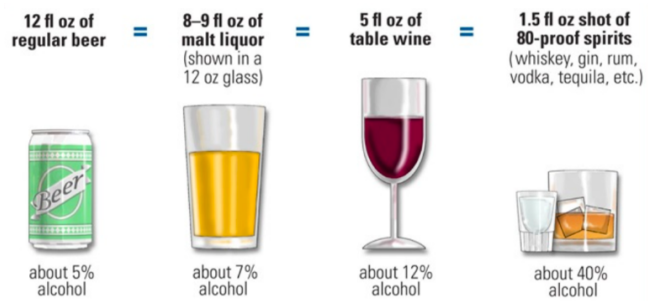
Edited by Emi Krishnamurthy and Gargi Nigam

To be honest, this was a very fun and also very alarming question to research and write about. A lot of what I learned, especially about the human brain, was surprising, but I was shocked to learn just how potent alcohol is — it can completely shut down entire regions of your brain.

There are many different types of memories, including long-term, short-term, and muscle memory. These are all stored in different, interconnected regions of your brain. Interestingly, binge drinking does not prevent you from creating or recalling memories. Rather, when you are blackout drunk, what you lose is the ability to store memories.

As many of us know, alcohol can affect cognitive functions including impulse control, attention, judgment, and decision-making. It does this by slowing down communication between neurons which affects how your brain processes information. Specifically, alcohol binds to receptors for a neurotransmitter called gamma-aminobutyric acid (GABA) which is responsible for calming and sedating your brain. By triggering this receptor, alcohol causes your brain cells to fire less and less frequently.

According to the National Institute on Alcohol Abuse and Alcoholism (NIAAA), when you drink large quantities of alcohol, it can start to affect a delicate region of your brain called the hippocampus, which is responsible for learning and memory.



The percent of "pure" alcohol (expressed here in alcohol by volume), varies by beverage. From the National Institutes of Health

This typically begins to happen at Blood Alcohol Concentrations (BAC) of about 0.16 percent, which is twice the legal driving limit. An average female begins approaching these levels after about 4 drinks in the span of 2 hours; for an average male, it takes about 5 drinks.

Buried deep within the temporal lobe, the hippocampus is a very complex part of your brain. Short term memories are transferred here for long term storage. The transfer of memories is a complicated process, and when you drink, communication between neurons in your brain is significantly impaired, making the memory-storing process difficult to impossible. This means that you are still making short term memories while you are blacked out, but you aren't storing them. These short term memories are shorter than you might think. According to Duke University, they only consist of the last 15-30 seconds. Anything longer than that will be transferred to your long term memory, or, if you are blackout drunk, lost.

There are different types of blackouts, which relate to the scale of memory loss. A "fragmentary blackout" — also known as a grayout or brownout — is the most common. This is when your memory of events is patchy or foggy. You can remember what generally happened, but there are large dark spots that you can't recall. This occurs as your hippocampus is beginning to shut down. The second type is known as an "en bloc" blackout and happens when the hippocampus goes entirely offline, and memory formation is completely blocked. If this occurs you won't be able to remember events at all: it will feel as if they never happened.

If you look up "blackouts due to drinking," most of the images you'll find are of people passed out. This is a common misconception, but "blacking out" is very different from passing out. During the latter, your entire body shuts down, but when you black out, you are still active. You can move around, and because you can still recall the last 15-30 seconds, you can have conversations with people, but brain function is significantly affected, and you lose the ability to store short-term memories.

So how much do you have to drink before you black out? There is no clear-cut answer. Your alcohol metabolism depends on your gender, your weight, how quickly you drank, what you ate that day, if you are taking any medications, and many, many other factors. It's important to remember that even if someone didn't consume that much alcohol, they could still be very intoxicated and possibly blacked out.

According to a 2016 study by Reagan R. Wetherill, roughly 50% of drinkers will experience partial or complete memory loss due to drinking at least once in their lifetime. If you decide to drink, it's important to check in with your friends multiple times throughout the evening to make sure everyone is safe. Although alcohol is one of the most socially accepted drugs, both its immediate and long-term effects can be severe.

FALL 2022 – SPRING 2023

September 25, 2022

A LOOK INTO MATHEMATICAL BIOLOGY

Written by Emily Almgren

Edited by Anagha Aneesh and Ashley Schefler

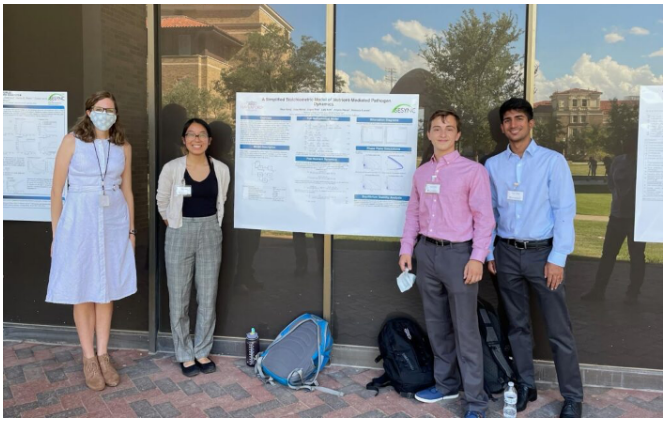
The real world is full of complex biological relationships. A rabbit population might fluctuate depending on the fox population, the amount of edible plants, and the spread of disease. Mathematical biologists like Associate Professor of Mathematics and Statistics Rebecca Everett make sense of these relationships using mathematical models. She explains that the mathematical models she creates represent biological systems much like a model airplane represents a real airplane. They are not perfect copies of reality, but they can be used to understand and predict what happens in the real world.

Professor Everett primarily uses differential equations to create her models. A differential equation is an equation containing a derivative, or a rate of change of a function. If P (t) is the population of squirrels on Haverford's campus at a given time t, the derivative of P (t), which we denote dP/dt, is the rate of change of the population of squirrels over time. Consider this assumption: the rate of change of the squirrel population is proportional to the current squirrel population. This makes sense considering that the greater the number of squirrels, the more they can reproduce. The phrase "is proportional to" tells us that the rate of change of the squirrel population is equal to the current squirrel population multiplied by a proportionality constant, which we will call k. We can now write the differential equation, dP/dt = kP.

This differential equation is an example of exponential growth. The differential equations Professor Everett uses are more complex than our dP/dt, but they often include an exponential growth term in addition to a death term and terms that depend on other differential equations in the model. For example, the squirrel population will decrease if the population of predators increases, so a differential equation for the squirrel population might include a term that depends on the hawk population. When considered together, these interrelated differential equations represent a complex biological system.

Professor Everett works in close collaboration with researchers who are experts in the subject of the model she is creating. These collaborators come to Professor Everett with a research question, and they discuss what should go into the model. There must be a balance between simplicity and complexity in these models: if a model is too simple, it does not accurately represent reality, but biological complexity makes mathematical analysis of the model more difficult. Professor Everett and her collaborators generally start with a simple model, and build up the complexity by gradually incorporating more factors.

One of Professor Everett's current areas of research is linking the currently separate fields of ecosystem and disease ecology. When the nutrients available to plants increases, they are better able to defend themselves against disease, but pathogens that cause disease in plants also benefit from an increase in nutrients. The question Professor Everett's ecologist collaborators want to answer is what happens in the long term when the amount of nutrients changes. The models she creates for this system are continuous, meaning that each equation has a value for every point in time. In a recent paper, Professor Everett and her collaborators use nine differential equations to model a deciduous forest. These nine equations correspond with nine variables, including the amounts of carbon, nitrogen, and phosphorus in the soil.



Professor Everett (left) and her research students Maya Gong '23, Logan Post '23, and Anay Mehta '23 (left to right) presenting at Texas Tech University in 2021.

Professor Everett also collaborates with psychologists to model the alcohol usage and craving of individuals with mild to moderate alcohol use disorder. The model Professor Everett and her collaborators created is discrete, so the equations are defined for only distinct timesteps. They use difference equations, the discrete version of differential equations. There are two equations in their model: one for alcohol use and one for craving. The model shows how these two factors relate, and Professor Everett and her collaborators plan to add complexity by adding equations for factors such as confidence in being able to reduce alcohol use. The ultimate goal of this work is to help psychologists individualize treatment for alcohol use disorder by shedding light on what factors cause individuals with the disorder to change their behavior.

Professor Everett emphasizes that her collaboration with psychologists is unconventional. Generally psychologists use statistics to gain information from data, not differential equations, so Professor Everett is excited that this research expands the range of mathematical methods used in psychology.

After creating a mathematical model, Professor Everett uses real-world data to evaluate its accuracy. For the model to be considered accurate, its predictions must match the expected results. Mathematical analysis can also show that the model makes sense. In most cases the solutions should be positive and bounded. For our squirrel example, this means that the number of squirrels should not be negative or approach infinity because these values cannot represent reality.

Once the model is created and shown to be accurate, it can be used to "experiment." Testing biologically can be expensive, impractical, or unethical, and a model offers a way to run tests mathematically. Researchers can observe long-term behavior and test how changing parameters affects the system.

Professor Everett's research is just one example of how mathematicians use math to understand the real world. Mathematical models are powerful tools that can be applied to a wide array of disciplines.

September 29, 2022

FALL 2022 STARGAZING: JWST PHOTOS AND JUPITER OPPOSITION

Written by Karen Masters, Professor of Astronomy and Physics at Haverford College

Edited by Emi Krishnamurthy and Anagha Aneesh

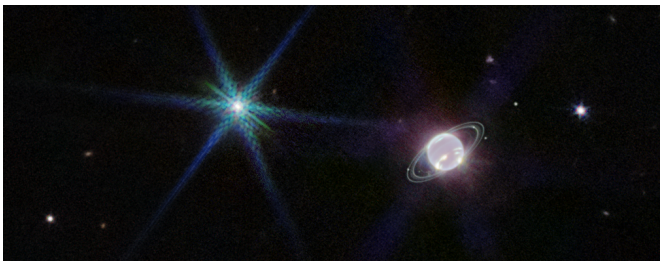
JWST Images

JWST, the "Just Wonderful Space Telescope" (here I am deliberately avoiding the official full name due to the ongoing name controversy, and instead amplifying Chanda Prescod-Weinstein's excellent renaming suggestion), has been wowing astronomers all over the world with its images of the cosmos since it achieved first light in February of this year.

It's tough to pick out just a couple of favorites from such a selection of beautiful images, but given my research interests in how spiral arms affect their host galaxy, my first pick has to be spiral galaxy IC 5332, seen with smooth spirals in the older Hubble Space Telescope image (which uses optical and UV light), but looking like a frothy mess in JWST (which uses infrared). Some fascinating astrophysics there for sure, which researchers will be spending time to work out.

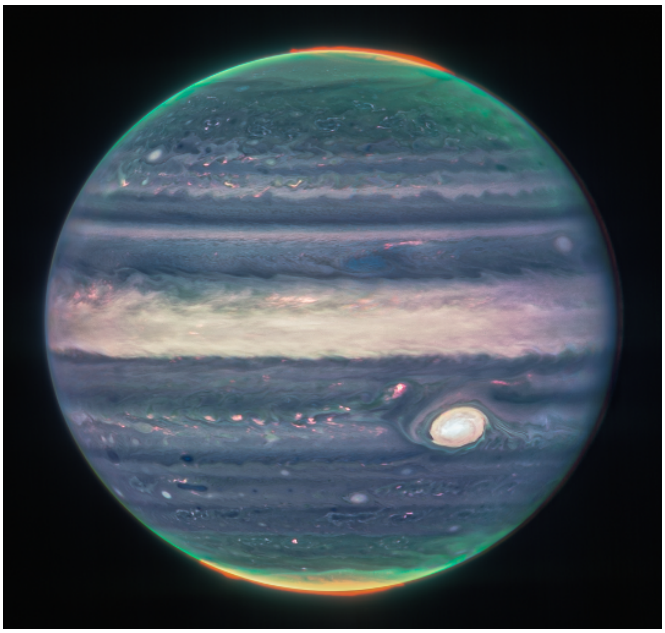
Two views of IC5332. On the left, HST shows large scale spirals, while on the right, JWST shows how they are all connected with each other. Image via NASA.

Next up is Neptune's rings. I bet you have all heard of Saturn's rings, but did you know that all of the outer planets have rings of some kind? Neptune's rings shine ethereally in this JWST image, the best view we've had of distant Neptune, famously the first planet discovered using calculus, since the Voyager mission flyby in 1989! The JWST image also features Neptune's bright moon, Triton, shown surrounded by the beautiful, six-spoked diffraction pattern of the telescope, which has hexagonal mirrors. I find this to be a fascinating illustration of the optics of light passing through apertures, which Haverford students can explore more in both PHYS102 and PHYS106 labs.



JWST image of Neptune (right) and Triton (left; with the six spokes of the diffraction pattern). Image via NASA.

I'll segue to Jupiter for my final JWST pick, with this stunning infrared image of the planet, revealing details of the cloud bands and storms, as well as light from Jupiter's aurora. So beautiful.



JWST image of Jupiter. Credit: NASA, ESA, CSA, Jupiter ERS Team; image processing by Judy Schmidt.

Jupiter Opposition

You might have spotted Jupiter in the news a lot recently because of its recent "opposition." The internet seemed to be overcome with how amazing Jupiter would look, urging people to get outside and view it. On September 26, 2022, Jupiter was at its closest point to Earth since 1963, however these close passes in general happen roughly annually, as the Earth overtakes Jupiter in its orbit.

Opposition literally means "opposite the Sun," from our perspective on Earth. At these times, Jupiter is high in the nighttime sky, and bright because it's relatively close. It makes a stunning sight every year. This year, the opposition happens close to a special point in Jupiter's orbit, known as the perihelion — its closest distance to the Sun. This makes the distance between Jupiter and the Earth a tiny bit less than it usually is at opposition, inspiring refrains like "the giant planet's closest approach to Earth in 60 years" and "closest in your lifetime." You can explore the Earth-Jupiter distance online.

This year Jupiter is a bit less than 2% closer than it was last year. The students running Public Observing nights at the Strawbridge Observatory were delighted with a stream of requests to view Jupiter the day this happened, but don't worry if you missed it — Jupiter remains very close, and a visually stunning sight for most of the rest of the semester. It's well worth a look — both with the unaided eye in the East just after sunset, and through our on-campus telescopes if you make it to a public observing night.

While not quite the JWST view, this image of Jupiter was taken by Reilly Milburn '20 using our on-campus telescopes, and gives a reasonable idea of the view you might get through the eyepiece.

In fact, the skies are full of planets this Fall, and these are some of the best sights to just enjoy in the night skies (if you can see them around the light pollution) as well as through small telescopes like the ones we have. As well as Jupiter, Mars will pass through opposition soon (December 8th) making it a bright object in the evening sky. Uranus also passes opposition, but that can only be seen in a telescope and isn't that exciting unless you know what you're looking at! Saturn passed through its opposition back in August, but remains also a bright evening object all Fall, a bit to the left of Jupiter.

While not quite the JWST view, this image of Jupiter was taken by Reilly Milburn '20 using our on campus telescopes, and gives a reasonable idea of the view you might get through the eyepiece.

Below is a screenshot from the free Planetarium software, Stellarium, showing the S-SE horizon around 10pm on Friday 21st October, with Mars, Jupiter and Saturn all lined up across the sky. From the Observatory, this is the direction back towards campus. You might need to head out across the athletic fields to get a low enough horizon to spot Mars.

September 28, 2022

WHY DOES COFFEE MAKE YOU POOP?

A QUIRKY QUERY

Written by Sooyeon Jung

Edited by Simon Thill and Sarah McNamara

Have you ever ordered an iced mocha with almond milk or an iced vanilla latte with oat milk before class and then later had to poop really badly during lecture? Well, according to science, you aren't the only one! In fact, about 30% of people need to use the bathroom after drinking coffee.

Contrary to popular belief, caffeine isn't the main culprit. In 2008, the National Library of Medicine published a study that tested the colonic function (pooping effect) of coffee by comparing caffeinated coffee, decaffeinated coffee, and water. While caffeine did play a role, the researchers found that decaf coffee increased colon activity, though not as much as caffeinated coffee.

Researchers believe that the biggest culprit is coffee's interaction with stomach acid. Caffeinated and decaffeinated coffee both stimulate a hormone called gastrin. Gastrin signals your stomach to produce more hydrochloric acid and digestive enzymes. This, in turn, promotes digestion and leads us to feeling the need to poop!

Our bodies also experience a gastrocolic reflex when we consume food or drink. This reflex, defined by the stomach "stretching," makes room for the new food by stretching your stomach and pushing out the old food. The gastrocolic reflex is stimulated by several biological factors and the hormone gastrin is one of them. Studies have also shown that this reflex correlates to our circadian rhythm, so your first coffee may stimulate your stomach even more.

However, you should never rely on coffee to poop, as coffee's effect on the colon decreases over habitual consumption. Too much coffee can also lead to an upset stomach, diarrhea, insomnia, anxiety, and headaches. So, drink in moderation and find your favorite campus bathroom to poop in safely.

October 4, 2022

POLIO RESURGENCE IN NEW YORK STATE PROMPTS RAPID PUBLIC HEALTH RESPONSE

Written by Andreas Wingert

Edited by Sarah McNamara and Emi Krishnamurthy

Poliomyelitis (polio) is a highly infectious virus that has no cure and can cause paralysis or even death. After nearly 40 years of no sustained poliovirus transmission in the United States (US), a case of paralytic polio was confirmed in New York, prompting a rapid public health response by local, state and national authorities.

The World Health Organization declared the US polio-free in 1994. But on July 21, 2022, public health officials announced a case of paralytic polio in an immunocompetent but unvaccinated young adult in Rockland County, New York. The patient had not recently traveled internationally; alarmingly, this suggested that the patient had acquired the disease through community transmission of the poliovirus. This recently-identified case spurred a rapid public health response.

The Centers for Disease Control and Prevention (CDC), New York State Department of Health, and local authorities issued an advisory to increase healthcare provider awareness, enhanced surveillance for potentially infected persons, tested wastewater from Rockland and surrounding counties, evaluated vaccination coverage in the patient's community, provided inactivated polio vaccine (IPV) to county immunization providers, and implemented vaccination clinics throughout Rockland County.

Genetically similar poliovirus (that is, poliovirus carrying similar genomic characteristics to that of the poliovirus isolated from the patient) was detected in at least 20 wastewater samples collected from New York's Rockland and Orange counties in May, June, and July 2022 (including samples originally collected for coronavirus surveillance), as well as in New York City sewage. Since this provides evidence of community circulation of the poliovirus, after these results were obtained in August 2022, additional outreach to local providers and syndromic surveillance were launched in order to detect symptomatic nonparalytic infection as well as asymptomatic infection.

According to the New York State Immunization Information System, the 3-dose inactivated poliovirus vaccine (IPV) vaccination coverage among infants and children aged <24 months living in Rockland County had declined from 67.0% in July 2020 to 60.3% in August 2022 (possibly due to the disruption of routine vaccination services during the COVID-19 pandemic), with the rate as low as 37.3% in one zip code. This compares with a New York statewide average of about 79% and a nationwide average of 92.7% for infants born in 2017 and 2018. The low vaccination coverage rate in Rockland County indicates that the community is at risk for additional cases of paralytic polio and, therefore, on July 22, 2022, the Rockland County Department of Health launched a countywide catch-up vaccination effort.

This recent case of polio has brought renewed attention to the importance of maintaining high vaccination rates against this potentially devastating disease.

October 3, 2022

WHAT ARE SPOTTED LANTERNFLIES, WHY SHOULD YOU KILL THEM, AND WHAT ARE HAVERFORD RESEARCHERS DOING TO FIGHT THEM?

Written by Sooyeon Jung

Edited by Simon Thill and Emi Krishnamurthy

Have you seen an insect with dots crawling on campus? When you try to kill it, does it jump and become a bright, flashing red? Does this insect escape easily, and when it does you feel deeply unsettled? Do your pacifist friends yell out when you try to stomp on it? Well, welcome to Pennsylvania, where the invasive species, the spotted lanternfly has completely taken over the state. Learn more about them, and why you are right in killing them.

If you are not from around Pennsylvania or the East Coast, this may be the first time you have ever seen this bug. It looks like a regular beetle-like creature, but when it "flies," it becomes a horrifying demon red. This is the invasive spotted lanternfly, Pennsylvania's #1 enemy.

The spotted lanternfly, an insect native to China, first came to the US in 2012. Its first US sighting was in Berks County, PA, about an hour away from Haverford College. Ten years later, in 2022, the spotted lanternfly infestation is prominent in 11 states: Pennsylvania, Connecticut, Delaware, Indiana, Maryland, Massachusetts, New Jersey, New York, Ohio, Virginia, and West Virginia.

Due to the locality of the issue, many Pennsylvania institutions are dedicated to learning more about the spotted lanternfly, including Haverford College. I talked to Dr. Suzanne Amador Kane, a Professor of Physics and Astronomy and Coordinator of Biochemistry and Biophysics at Haverford. Her research, which started in 2019, focuses on the biomechanics of the spotted lanternfly. When asked about her inspiration for starting her research, she said that when she found her garden and car covered with spotted lanternflies, she tried to kill them but noticed that the bugs would avoid her by jumping and falling over.

Through their research, Professor Amador Kane and her research group found that, contrary to its name, the spotted "lanternfly" rarely flies. Immature black and white spotted lanternflies are unable to fly and only hop. While the adult spotted lanternflies have brown wings and can fly, they primarily use wings to glide and hop. When it hops, it exposes its red hind wings, which also have black spots.

Interestingly, the group found that these insects, starting from their immature age, are incredible gymnasts. They use "falling" as a survival mechanism. Young spotted lanternflies pretend to dramatically fall, yet they can steer themselves in the air, despite not yet having their wings. Dr. Amador Kane has found that spotted lanternflies diffuse nearly all of their energy upon landing. They use their body mechanisms to increase their chances of landing upright. They also found this applies to a variety of surfaces including hard, leafy, and angled.

A mature spotted lanternfly, by Matt Rourke on AP Images for CNN.

Now, Professor Amador Kane's research is focusing on attempts to trap and mitigate the spotted lanternfly. Thus far, spotted lanternflies have been evading researchers' various attempts to eliminate them. Professor Amador Kane's research group is working to find out why. Currently, many of the traps used are not working, and pesticides, currently used to control spotted lanternfly populations, affect all insects. While some suggest mechanically removing lanternfly eggs from tree bark, the spotted lanternfly have started to lay eggs higher up in trees, preventing the average person from easily removing the eggs. Research has also shown that natural predators do not particularly prefer eating the spotted lanternfly. Hopefully, the work done in Professor Amador Kane's lab can help us design new effective traps and mitigate the population.

Professor Suzanne Amador Kane's message to the Haverford community: "While the spotted lanternflies are fantastic and have fascinating behaviors, please, please, stomp them. The spotted lanternfly causes damage to many crops, especially in Pennsylvania. Because of the spotted lanternfly, Pennsylvania is at risk of losing hundreds of millions of dollars and hundreds of thousands of jobs in agriculture.

The spotted lanternfly causes damage by feeding and laying their eggs in crops and completely covering trees. In addition to damaging trees, vines, and crops, when spotted lanternflies feed, they excrete a sap called honeydew that allows black sooty mold to grow on what is left on the crops. This mold causes damage to plants, stopping their growth. They lay eggs in masses of about 30-50 eggs each, causing exponential population growth.

Even though the spotted lanternfly is not able to fly far, they hitchhike on tree bark, lawnmowers, bikes, grills, transportation, etc. As a Quaker school, Haverford tries to uphold the nonviolent ideals of Quakerism. However, for the environment, the Department of Agriculture strongly suggests that if you see a spotted lanternfly, smash it with your shoe. If you see a spotted lanternfly egg mass, which is about an inch long and looks like mud, scrape it off with something and crush them. This is especially important as it is soon time for the spotted lanternflies to start laying their eggs. If you see this invasive species outside of the 11 states mentioned earlier, please make sure to report your findings to your state department of agriculture.

Thank you to Professor Suzanne Amador Kane for sharing her research. Learn more about her research here.

January 23, 2023

HOW DO BLUETOOTH AND WIFI WORK?

A QUIRKY QUERY

Written by Simon Thill

Edited by Maya Cheam and August Muller

This is a great question! We all use bluetooth and Wi-Fi every day, but how do they actually work? They are more similar than you may think, and you'll be surprised to find out just how many other devices use similar technology.

Bluetooth speakers, along with other types of devices like microwaves, baby monitors, car alarms, and Wi-Fi operate using ultra-high frequency radio waves in a range between 2.400 and 2.4835 gigahertz (GHz). This has been set aside by the international agreement for the use of industrial, scientific and medical devices. Radio waves are part of the electromagnetic spectrum, just like visible light, infrared, and X-rays. They can be created by passing electricity through an antenna as shown in the figure below. Radio wavelengths are very long, much longer than the width of an atom which means they are invisible to humans and can pass through objects like walls and furniture unobstructed. This is why you can maintain a connection even if your two devices are in separate rooms.

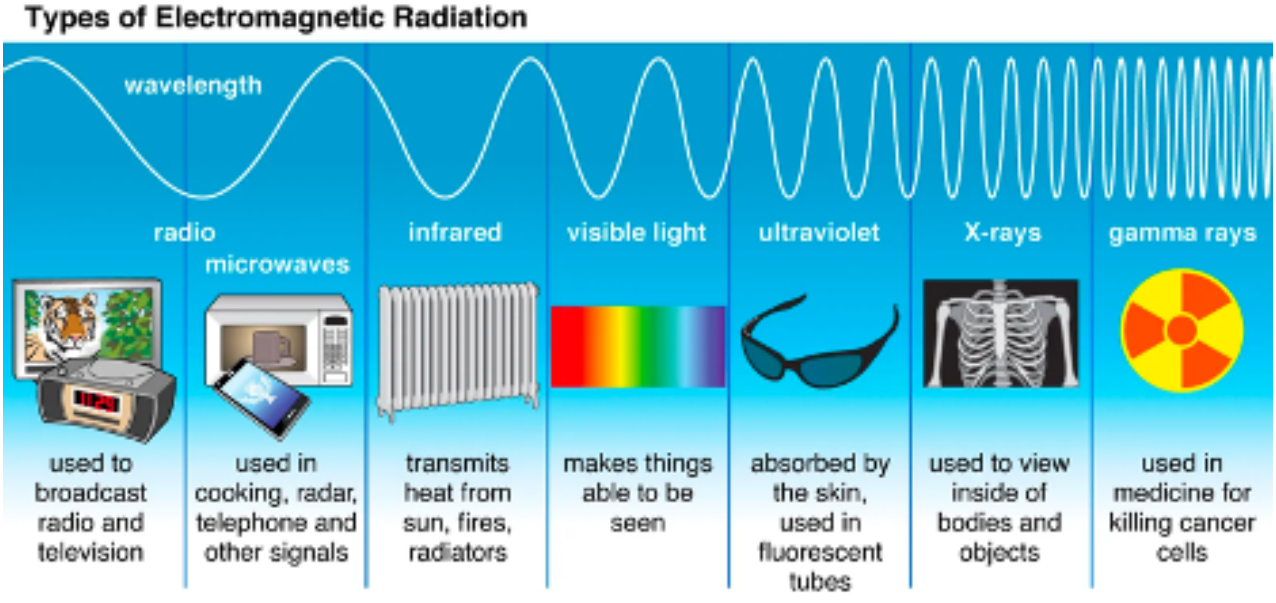
If you want a quick recap from trigonometry, frequency is how many wave peaks occur per second and wavelength is the distance between two peaks. All waves travel at the speed of light, so frequency and wavelength are related—we can always get one from the other.

Your electronic devices contain an antenna that can both send and receive radio waves and differentiate between tiny changes in frequency. Just as your eyes can tell the difference between 545 terahertz (THz) green light and 430 THz red light, the antenna in your bluetooth device can tell the difference between 2.477 GHz light which it interprets as a 1, and 2.417 GHz light it reads as 0. Your phone can switch between emitting different frequencies 60 million times per minute which means it can send 1 million 1s and 0s every second!

A computer chip in your devices receives all of these 1s and 0s and can transform them into the audio you hear. Everything is sent in bursts called packets. Each packet consists of an access code, a header, and a payload. The access code synchronizes your devices and ensures that information is being transmitted to the correct device. The header contains basic information about the size of the package. Finally, the payload, which can vary in size, but is the largest portion of the package and contains your audio. The computer chip in your speaker is programmed to convert this data into sound.

Bluetooth is two-way data transmission, meaning that both your audio playing device and your speaker send packets. For instance, your speaker can send pause, play, or skip forward commands to your audio playing device. To pair, typically both devices must be activated and "discoverable," broadcasting information about themselves. While some devices are always discoverable, others require a pairing mode for activation. Once paired, both devices agree on two specific frequencies in the 2.4 to 2.4835 GHz range which will represent a 1 or 0. This is a fairly wide range, so even if there are multiple bluetooth devices operating in the same room at the same time you won't have interference.

If you're happy with this explanation of bluetooth, you can stop



reading here. In the upcoming section, I cover more of the technical details about adaptive frequency hopping.

The 2.4 to 2.4835 GHz radio wave range used by bluetooth devices to communicate is divided into 79 different channels. Each channel has a different set of 2 frequencies that represent a 1 or a 0. There are so many channels to limit the amount of interference between all of the different devices that operate within this range.

Previously, I simplified the concept of device connection as if your devices choose one specific channel, with one frequency for 1 and another for 0. This is not totally accurate. What actually happens is your devices change channels 1600 times a second. That means every 1/1600 of a second, two new frequencies are used to send and receive data.

The order is dictated by the device playing audio, and is agreed upon when the devices pair. If a channel is noisy, which often occurs from overuse or interference at that time, your devices will adapt and not broadcast over that band. This adds an additional level of security, since anyone trying to listen won't know the channel sequence. It also helps to further limit the amount of interference between bluetooth devices.

Every time the channel changes, a packet of data is sent either from your speaker or your device, which alternate sending and receiving data. This same process happens when you connect to Wi-Fi, although only over 14 channels.

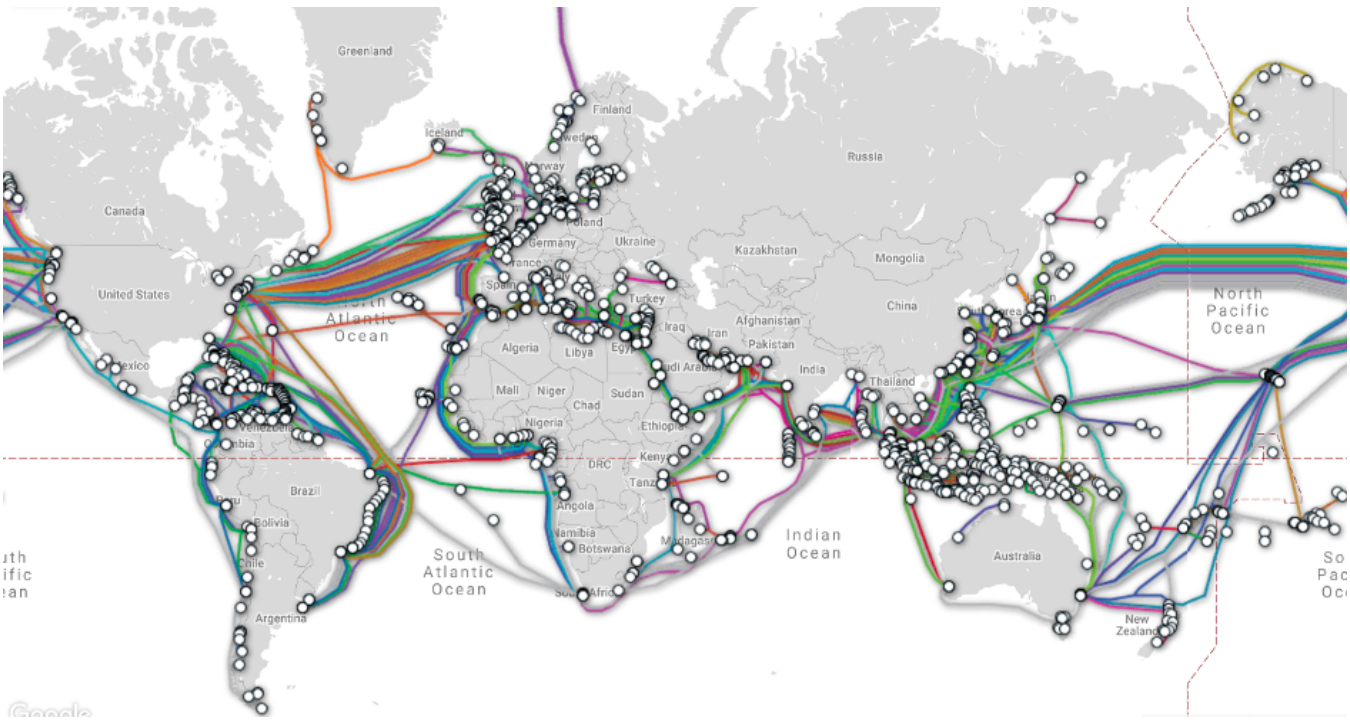
What is Wi-fi?

Every line in the image below is an underwater internet cable which connects computers around the world. Of course, there are just as many cables on land as well. This "world-wide-web" of wires means that any connected computer can communicate with any other connected device, anywhere in the world. This is the internet. How it all works is incredibly fascinating, but is unfortunately not covered in this article.

Wi-fi stands for Wireless Fidelity and allows you to connect to the internet without the need for a physical wire (ethernet cable). When your computer is connected to Wi-Fi it sends out radio waves to a wireless router which is connected to the internet by an ethernet cable. This connection is very similar to bluetooth, they even use the same 2.4 GHz frequency, but with some key differences.

Wi-Fi uses stronger radio waves with a larger amplitude so that waves suffer less interference and can propagate farther. This is why you may notice that Wi-Fi has a much longer range than bluetooth. Wi-Fi can also transmit 54 times as much information, again all in the form of 1s and 0s. The exact process of how your router converts this into an internet traffic request is beyond the scope of this article. Finally, if you've ever noticed your connection vastly improves from just moving closer to the router, this is because Wi-Fi can switch from the 2.4 to a 5.8 GHz frequency band to transmit a larger amount of data but only over shorter distances.

Both bluetooth and Wi-Fi are incredibly complex ways of transmitting data. I didn't even touch on how signals are analyzed and turned into a sound file or website, never mind the advanced circuitry and hardware involved in this process. I merely covered the very basics of how radio waves can be used to send messages. I hope you enjoyed this article. Keep asking quirky queries!



February 6, 2023

BIG PHARMA'S AGENDA

Written by Sooyeon Jung

Edited by Anagha Aneesh, Masha Kilibarda, and August Muller

I am constantly buying prescription medications. Is it because I like walking to the store? Of course not. Like millions of other Americans, I do this because my life depends on it. Even though these tiny pills are a vital part of people's lives, major pharmaceutical companies, or Big Pharma, insist on high prices. Drug companies claim that the profits go into the funding for research and development; however, drug companies often spend just as much or even twice as much money on marketing. Instead of focusing on making the drugs accessible for people who need them, Big Pharma actually concentrates on trying to profit off the drugs. The same year, the CEOs of the major pharmaceutical companies Allergan, Johnson & Johnson, and Pfizer Inc earned a total of $90 million.

Big Pharma receives assistance from the federal government, making these high prices especially out of control. For example, the National Institute of Health (NIH), a sector of the US Department of Health and Human Services, invested over $100 billion from 2010 to 2016 that resulted in the discovery of 210 approved drugs. The government also gives companies tax breaks from these research discoveries. According to the federal research and development tax credit, companies can benefit if they are making attempts to manufacture new drugs or treatments. So, even though pharmaceutical companies are receiving grants for research and development, they are claiming that the high costs of drugs are due to the same exact reason. How does that make sense?

By focusing on making profits for pharmaceutical companies, Big Pharma is putting people's lives at risk. A very unfortunate yet common example is insulin. For people with diabetes, it is a necessity. Having high blood sugar for too long can result in permanent damage to the eyes, nerves, kidneys, and blood vessels, or result in death through heart issues or a stroke. By using insulin, diabetics can keep their blood sugar levels in check. For this reason, insulin is not a choice for diabetics - it's a necessity. However, NovaLog, the brand name for insulin aspart (a specific type of insulin that acts quickly) is sold at anywhere between $14 and 300 a vial in the United States. In comparison, in Singapore, it costs $48, $14 in India, $6 in Austria, and $0 in Italy and other European countries.

Apart from high prices, drug companies attempt to profit by monopolizing their drugs through patents. Big Pharma uses "evergreening," which is the process of using legal and business tactics to extend a patent that is about to expire. For example, if a patent for a drug is about to expire, the pharmaceutical company will add a stripe to the pill or slightly alter its chemical composition to prevent the drug patent from entering public domain. Evergreening blocks other companies, especially smaller ones, from manufacturing the drug which would make the drug more accessible and cheaper.

When the federal government attempted to create legislation to allow drug negotiation for Medicaid patients, Big Pharma spent over $100 million on lobbyists. They claimed that by reducing their prices, they would "kill innovation." However, Dr. Aaron Kesselheim, who leads the program on Regulation, Therapeutics, and Law at Brigham and Women's Hospital in Boston, says that since 1906, Big Pharma has used the same exact rebuttal, and it has never been true.

There is no doubt it is impossible to both maximize profits and save as many lives as possible. And, pharmaceutical companies have chosen to focus on maximizing their own profits. There must be a "fundamental extension in morality." And right now, there is no morality in any of the decisions Big Pharma has made, and Americans have no choice but to succumb to Big Pharma and pay in order to live. In 2018 alone, Americans spent $535 billion on prescription drugs, and 58 million adults reported to be unable to pay for necessary drugs in 2019. In my mind, there is no doubt that Big Pharma is responsible for millions of deaths related to the lack of access to medicine.

February 13, 2023

WHY PEOPLE CHEAT

Written by Sooyeon Jung

Edited by Anagha Aneesh, Gargi Nigam, Ashley Schefler, and Masha Kilibarda

This past year, many celebrities have been involved in cheating scandals. Some of these affairs have resulted in fantastic songs, like in the cases of Miley Cyrus and Shakira. Some have resulted in silence. Several shocked the nation. Others have not surprised anyone. Why do people commit infidelity? Is there a scientific explanation behind it? Let's explore some possible explanations.

In 1970, scientists studied some overarching personality qualities among humans. They determined that everyone's personality consists of the Big Five factors: "openness to experience, conscientiousness, extroversion, agreeableness, and neuroticism." Since 1998, there has been research largely focused on finding a specific personality type that was the most likely to commit infidelity in their marriage. They concluded that among the Big Five factors, there were some traits which correlated with infidelity. Generally, people with high extroversion traits were more likely to cheat. In addition, partners of those with high neuroticism, high narcissism, or high extroversion traits were also likely to be unfaithful. In 2015, scientists did further research on why people commit infidelity. Common responses included having poor self-control, being selfish or angry, seeking attention, and feeling bored or insecure. Now, this doesn't mean that if you are an extrovert or have poor self-control, you are likely to cheat. This is simply a trend noticed by the study.

Recently, there has been more interest in exploring the biology behind cheating, and researchers found a connection between hormone levels and cheating. It was discovered that men in relationships had testosterone levels 21% lower than men who were single. Another study showed that when men had higher levels of testosterone in a relationship, they had more interest in having sex outside of their relationships.

This hormonal relationship has been found to manifest in voices as well. People tend to find men with deeper voices more attractive due to the perceived notion of higher testosterone. However, women who want a long-term relationship were found to avoid men with deeper voices. They found there was an instinct of associating higher testosterone with a guy's potential for cheating.

Men are not the only ones subject to the biological effects of hormones. For women, the ovulatory cycle is a factor in infidelity. Women are more likely to cheat when they are most likely to get pregnant (aka when they are ovulating). While most women probably do not want to get pregnant at the time of initiating an affair, from an evolutionary aspect, their bodies believe that they are constantly searching for the best partner.

While it seems that there is biological reasoning for cheating, it is clear that infidelity cannot be solely based on hormones. As human beings, we have control over our own actions. No one cheats solely based on "the science." So, take this article to remember that your actions are your own and you can make an active choice not to cheat!

FALL 2023

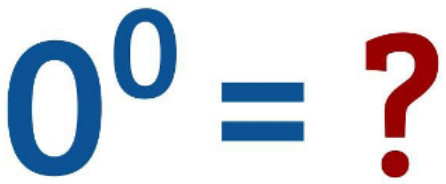
September 14, 2023

WHAT IS ZERO TO THE POWER OF ZERO?

A QUIRKY QUERY

Written by Emily Almgren

Edited by Simon Thill and George Morgulis



We know that a nonzero number to the power of zero is one and zero to the power of a nonzero number is zero. So what is zero to the power of zero? Is it One? Zero? Undefined? It turns out that there is no single accepted answer — and this illustrates that mathematical definitions are not objective.

We know that a^3 is equal to a multiplied by itself 3 times, or a•a•a. Then, 0^3 is 0 multiplied by itself 3, which is still 0. That gives us the pattern:

$$0^3 = 0$$
$$0^2 = 0$$
$$0^1 = 0$$
$$0^0 = ?$$

This suggests that $0^0 = 0$, but it is not the whole story. What happens when we start with negative exponents and work our way up? We know that $0^{-3} = 1/0^3 = 1/0$, which is undefined. That gives us the pattern:

$$0^{-3} = \text{undefined}$$
$$0^{-2} = \text{undefined}$$
$$0^{-1} = \text{undefined}$$
$$0^0 = ?$$

Now things are not so clear. The positive exponents tell us that $0^0 = 1$ and the negative exponents tells us that 0^0 = undefined. Let's look at this another way. We know that $3^0 = 1$, so we have the pattern:

$$3^0 = 1$$
$$2^0 = 1$$
$$1^0 = 1$$
$$0^0 = ?$$

So now there are three possibilities: zero, undefined, and one. How do we choose? The answer is that we can do just that: choose. But we should choose carefully.

It was mathematicians who chose to call 1/0 undefined and warn us against dividing by zero, and this is for a good reason. If we say 1/0 is equal to some number x, then we are really saying that 0•x = 1 If we follow the rule that zero multiplied by any number is zero, then 0 = 1. So, if we choose to divide by zero we need to accept that 0 = 1.

The 1/0 example illustrates how mathematical definitions are constructed. In the real world, zero squirrels is not the same as one squirrel, so it makes sense to avoid saying that 0 = 1. To do this we must define 1/0 as undefined. The question of zero to the power of zero is not as clear as dividing by zero.

The most commonly accepted answer is $0^0 = 1$, but some mathematicians use 0^0 = undefined. This choice depends on which is most useful and consistent given the context.

One reason why $0^0 = 1$ is generally preferred is that it's consistent with the combinatorial definition of the exponent for integers, which says that ab is the number of ways to form a set of b elements from a set of a elements. There is one way to form a set of zero elements from a set of zero elements, so this means that $0^0 = 1$.

The ambiguity of zero to the power of zero reveals that math is not a set of pre-ordained rules. Mathematicians intentionally design definitions and axioms — statements like 1/0 undefined that are assumed to be true–and the rest of math is what logically follows.

October 26, 2023

WHY INDIA'S LUNAR LANDING WAS CHALLENGING AND MONUMENTAL

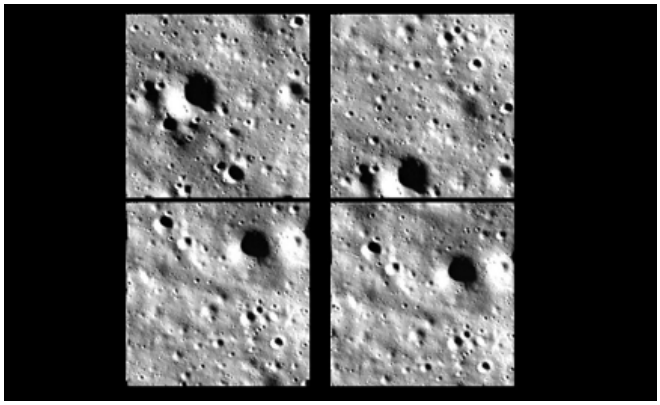
Written by Viraj Singhania

Edited by Simon Thill and Emi Krishnamurthy

The Indian Space Research Organisation's (ISRO) Chandrayaan-3 (translating to 'Moon Vehicle-3') landed on the south pole of the moon on the 23rd of August, 2023, making India the first country to do so. The south pole of the moon is sought after by all space-faring nations, and landing there marks a big achievement for India. While this accomplishment is being celebrated globally, not many are aware of the significance of this feat. Why does everyone want to land on this side of the moon? Why is it so difficult to do? What does this mean for the future of space exploration and space travel?

The primary reason for landing on the south pole of the moon is due to the water. This region of the lunar surface hardly receives sunlight due to the moon's axial tilt, making it constantly cold and very effective at trapping ice, which never warms up enough to escape in its liquid or gaseous state. The presence of frozen water is helpful for a myriad of reasons. It can be used as drinking water for astronauts or as a coolant for spacecrafts and machinery. Furthermore, water is made up of hydrogen and oxygen molecules and can be split to produce oxygen gas that astronauts can use to breathe. Lastly, perhaps the most important use for lunar ice, water can be broken down into liquid H2 and O2. While that might sound a little pointless, those two liquids are commonly referred to by another name when used together: rocket fuel. Liquid hydrogen and oxygen can be used by rockets to refuel, making it viable to create lunar bases from which space missions can be launched. While this is a possibility only in the far future, it is a very real possibility. All these uses for lunar ice explain why countries want to get to the south pole, but why is it so difficult?

Image of LVM3-M4 Rocket carrying Chandrayaan-3 taken at launch. (Image credit: ISRO)



Images of the lunar south pole's surface taken during Chandrayaan-3's descent. (Image credit: ISRO)

What we desire from the south pole of the moon is what also makes landing there difficult. Lunar ice is slippery and uneven, making it a terrible landing site for a spacecraft. This region of the moon is also filled with craters and hills. Usually, probes work around this issue by using cameras to navigate away from geographical protuberances towards flat land, but this can't be done properly on the dark side of the moon because it is completely shrouded from light. Moreover, signals from earth can't reach a craft reliably, which means that the probe cannot be remotely controlled and monitored. A little bad luck can mean losing signal with the spacecraft and mission failure. Lack of sunlight also means that the craft cannot use solar power to indefinitely operate on the lunar surface. The craft must also be built to withstand the cold temperatures which can go as low as -250 degrees Celsius (-418 degrees Fahrenheit). Russia's Luna-25 probe failed to land on the south pole of the moon just days before India. This is likely due to the multitude of challenges and limitations of landing in this region. Regardless, India managed to land in and collect data from this region. What can this accomplishment do for the endeavour of space travel?

The data collected by the probe itself is largely irrelevant to the general populace. The probe collected data on temperatures across various depths, slight seismic activity, and even detected sulfur molecules, according to a 2023 article from CNN. Aside from this data, India has shown the world that landing on the South Pole is possible with current technology. Moreover, the Chandrayaan-3 mission only cost about 75 million USD. For context, NASA's Artemis 1 rocket, which orbits the moon, cost about 13 billion USD over 25 years. This lunar mission's most important objective was successful, which was to inspire the rest of the world. With future missions to the south pole being planned by the US and China such as the Artemis, Viper and Chang'e-7, India set an important milestone by being the first to land on the dark side of the moon.

Recently, the lander was put to sleep for a period of 2 weeks after going into complete darkness. It was supposed to wake up on the 22nd of September, but it sadly seems to be dead. The Vikram lander was supposedly unable to tolerate the harsh conditions of the South Pole for too long, according to the Indian Express (2023). Regardless, the mission achieved its purpose and collected valuable data. It is still considered to be a massive success for India and humanity.

December 16, 2023

PHYSICAL ACTIVITY IS EFFECTIVE FOR IMPROVING SYMPTOMS OF MENTAL HEALTH CONDITIONS

Written by Andreas Wingert

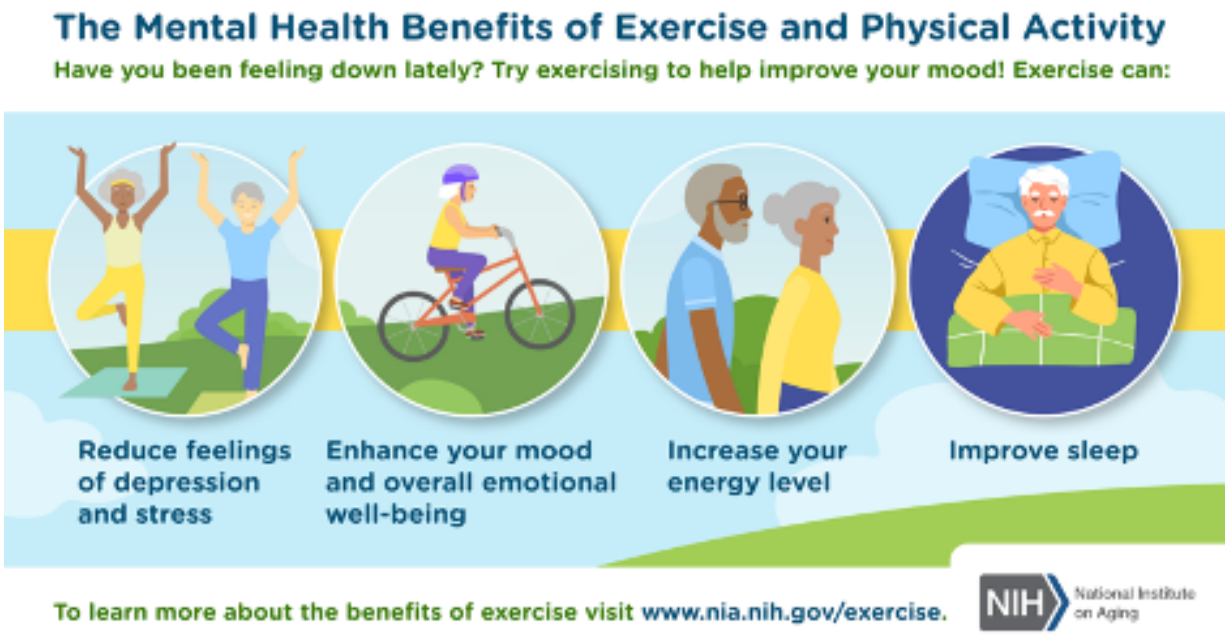
Edited by Simon Thill

Depression and anxiety are among the most common mental health disorders, often having detrimental and disruptive impacts on people's lives (Patel V et al., Global Health Data Exchange). A systematic review, published in the British Journal of Sports Medicine, including 1,039 randomized controlled trials and 128,119 participants found that physical activity, defined as "any bodily movement produced by the contraction of skeletal muscles that results in a substantial increase in caloric requirements over resting energy expenditure," is associated with a 43% reduction in symptoms of depression, anxiety, and psychological distress compared with usual care.

The effects of physical activity on mental health symptoms were similar across a wide range of adult populations, including the general population, people with diagnosed mental health disorders, and people with chronic disease. However, the largest reductions in mental health symptoms were observed in people with depression, pregnant and postpartum women, apparently healthy individuals, and individuals diagnosed with human immunodeficiency virus or kidney disease.

All modes of physical activity were beneficial, including aerobic, resistance, mixed-mode exercise, and yoga. A study published in the Handbook of Sport Psychology states the beneficial effects of physical activity on mental health symptoms may be due to a combination of psychological, neurophysiological, and social mechanisms. Previous research has shown that different physical activity modes induce different physiological(Rivera-Brown et al.) and psychosocial effects(Rivera-Brown et al., Carin-Levy et al.), and this is supported by the results of the systematic review. For example, resistance exercise demonstrated the largest effects on reducing symptoms of depression, while yoga and other mind-body exercises were most effective for reducing symptoms of anxiety.

Higher intensity physical activity was associated with more improvement in mental health symptoms. Low-intensity physical activity may be inadequate to stimulate the neurological and hormonal changes associated with larger improvements in depression and anxiety (Handbook of Sport Psychology). The review also analyzed the effectiveness of different durations of physical activity and found that the effectiveness of physical activity in improving mental health symptoms decreases with longer periods of exercise. This finding may be due to a decline in adherence with longer exercise periods or perhaps because the benefits of physical activity plateau after a certain period of time. Physical activity is a cost-effective and accessible intervention that can be readily implemented in most healthcare settings. However, exercise should not be viewed as a substitute for current treatments such as counseling and medication, but rather as an adjunct treatment and part of a comprehensive management approach to optimize mental health by reducing symptoms of depression, anxiety, and psychological distress.



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