ISSUE 35 Spring 2018

NU SCI

MOTION

Staff

President
Gwendolyn Schanker

Editor-in-Chief
Sage Wesenberg

Senior Editors
Jameson O'Reilly
Cicely Krebill

Chief Design Officers
Annie Lee
Kristi Bui

Chief Marketing Officer
Jackson Griffiths

Outreach Ambassador
Adrianna Graziano

Webmasters
Erica Yee
Amanda Bretti

Editing
Adanya Lustig
Adrianna Graziano
Erica Yee
Fayez Ghazi
Heather Offermann
Lucas Cohen
Lucas Principe
Rafi Razzaque

Design
James Goulart
Lillie Hoffart
Anna Li
Julie Murmann
Victoria Pajak
Yechang Yang

Marketing
Moustafa Abdelaziz
Catu Beretta
Irene Ok
Krithi Nathan

Staff Writers
Denny Truong
Paula Hornstein
Hugh Shirley
Christina Weber

Cover Design by Irina Pyataeva

Letter from the Editor

In this day and age, it seems harder and harder to sit still. Everything around us is always on the move. Blurs of students rushing to their next class. Flocks of geese flying away from the brutal cold. Remarkable Olympic athletes. Icebergs melting. Diseases spreading. Cars driving themselves.

From one day to the next, movements of massive and infinitesimal proportions are equally present all around us. And to kick off our first issue of 2018, NU Sci is exploring those movements in Issue 35: MOTION.

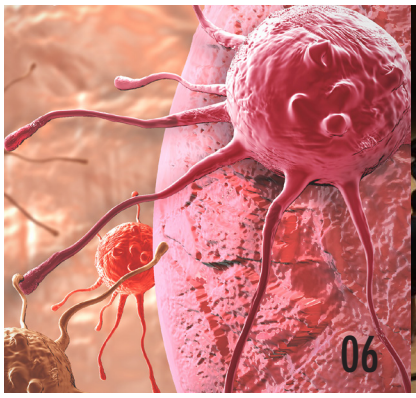
This semester, we were lucky to have a record number of writers - new and returning - at our first meeting in January. Squeezing into our room on the fourth floor of Ryder Hall, I was thrilled with the excitement in the room about the many possible article topics. With everything from robots who can move like humans, to the elaborate mating dances of birds, to the world's fastest marathon runners - Issue 35 is on the move.

The work of our 40+ writers not only graces the pages of this magazine, but also our website. After you've finished reading through the magazine, I'd encourage you to head over to our website at nuscimag.com to read about squirrel dexterity and the motion of stars. You can also learn about the connection between climate change and earthquakes, supercomputers solving traffic problems, and deaf fish that can sense the water's movements.

With a larger group of writers than ever, this issue would not have been possible without the incredible dedication of the team of editors I am so lucky to work with this year, many of whom have carried on their editing duties from last semester. They have devoted much of their time not only to writing their own articles, but to working one-on-one with writers to brainstorm and problem-solve - collectively editing over 60 articles. They, along with our other excellent team members who carry the magazine from conception to publication, manage all of this on top of challenging coursework and co-ops.

Science is constantly moving forward, and so are we. So on behalf of all of us here at NU Sci, we present to you - motion. As everything in your world whizzes by, take a few minutes to slow down, relax, and read about the amazing science behind it.

Sage Wesenberg
Editor-in-Chief



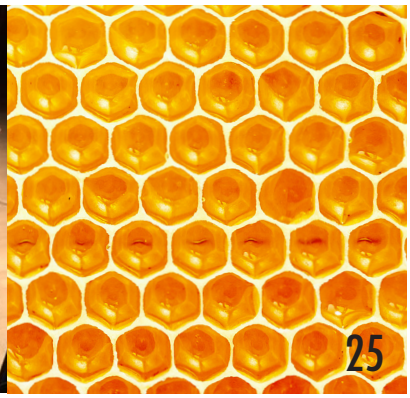


Table of Contents

FIGHTING DISEASE AROUND THE WORLD

Northeastern professor studies pandemics in the African diaspora

BY ADANYA LUSTIG, LINGUISTICS, 2018

DESIGN BY ANNA LI, BEHAVIORAL NEUROSCIENCE, 2018

Richard Wamai, professor in the department of Cultures, Societies, and Global studies at Northeastern, researches and teaches about infectious diseases in the African diaspora. He started out with a bachelor's degree in sociology and philosophy from his home country of Kenya and since then he's worked and studied at several prestigious institutions, from Johns Hopkins to the World Bank to Harvard. From there, he went on to study public policy and eventually public health. Professor Wamai joined the faculty at Northeastern almost 10 years ago to continue his work on neglected tropical diseases, HIV, and HPV.

NU Sci sat down with Professor Wamai to talk about his background and recent sabbatical that took him to Kenya and Ghana.

Q. Did you always know that you wanted to study diseases in the African continent?
A I knew that. So, [in] 2001, my brother, who's older than me, passed away with HIV in Kenya. And I remember, my dad was a public health officer in the village in the colony era, in the 1950s. He was the person in charge of providing public health services, educating people about diseases. He was involved in the smallpox eradication, TB work, and even basic things like nutrition and sanitation.

I look at Kenya. I grew up there and I built my field of expertise [and] foundational training there. And there's things I can do there. I can do a lot of work there.

When I joined Northeastern, I was doing HIV work and I started understanding the disease profile among African immigrants, who have come from the African continent to the US with HIV. But I was still very interested in the disease profile on the continent but I've also shifted a bit. First HIV, and then neglected tropical diseases, and then [cervical] cancer. Also, leishmaniasis is very concentrated in the eastern African region. That disease has also drawn me back into the east African region, but I've worked across about 18 countries in Africa.

Q. We've talked a lot about epidemics and pandemics, what interests you about pandemics?
A. Of course, there's this big disease idea. In 2005, there were three large trials, randomized controlled trials, targeted toward determining whether male circumcision has an effect on reducing the risk of HIV infection. The results of these studies were extremely positive – they showed there's a 60 percent risk reduction in heterosexual men, in reducing the risk of onward infection. There was a cluster of scientists working on HIV [at Harvard] . . . I was in the right place at the right time, when these studies had been completed.

> "I look at Kenya. I grew up there and I built my field of expertise [and] foundational training there. And there's things I can do there. I can do a lot of work there."

Q. You just came back from a sabbatical this semester. What were you working on?
A. Multiple projects. The first is the visceral leishmaniasis project. I was there in December. Two students came with me to the field, collecting data, visiting health facilities with me. I'm developing a research center in northern Kenya. In this project we're doing clinical work, health education, and vector control.

In this community, we screen all diseases, not just visceral leishmaniasis, because in this village, this would be the only time they will have contact with health workers. It is the only opportunity to see a clinician. We provide drugs. We carry our meds with us. We were able to screen for about 25 diseases and provide intervention for those we can in the field, like malaria.

I was in Western Kenya working on another project on health insurance. Universal health care coverage is a global goal. In rural settings in Kenya, a lot of people don't have health insurance. As a result of that, people who are poor do not have access to health care. Or, people who have health care, might become poor as a result of health care costs. We know that people who are poor will be adversely affected when they have a disease, so the global goal is for everyone in every country to have access to affordable health care.

Does Diet Have an Expiration Date?

The difference aging can have on dietary choices and habits

BY CHRISTINA WEBER, CELL AND MOLECULAR BIOLOGY, 2020 DESIGN BY JULIE MURMANN, BEHAVIORAL NEUROSCIENCE, 2021

A common misconception is that our brains are fully matured by our early twenties; however, it is actually not even fully complete until you are around 30! Does that change anything? Well, it should. Based on the maturation of your brain, your diet needs to be altered to assist you in reaching your full potential. Whether it be for your overlying mood or for the underlying neurochemistry, the foods you eat and the actions you take can impact mental health and resulting behaviors.

A new global study from Binghamton University focused on the differences in mental states and food intake between young and mature adults, with young adults ranging from age 18 to 29. This cross-sectional study, done through a global anonymous food mood questionnaire, was intended to focus on dietary factors, practices, and exercise in relation to mental states; particularly, mental distress.

> "Exercising more than three times a week decreases mental distress."

Nutrient consumption patterns and specific dietary regimes were targeted for the study in relation to their effect on mental state. This was done by picking foods that correlate with neurobiology. The chemical pathway that consists of neurotransmitters crossing synapses leads to mood changes based on changes in food choice. Dopamine and norepinephrine are two types of these mood-affecting neurotransmitters. An example of this is eating meats rich in protein to attain tyrosine and phenylalanine, which can lead to dopamine increase, positively affecting mood.

Healthy lifestyle choices were studied to test their effects on further health-promoting behavior including healthy diet, healthy dietary practice, and exercise. Healthy diet includes food like whole grains, fruit, and vegetables whereas healthy dietary practices include eating breakfast, taking vitamins, and eating fish oil. The researchers separately varied each of these behaviors to be able to determine their impact on each other as well as impact on overall mood of the participants, and statistically analyzed the results.

One of the main results from this study is that these choices of healthy lifestyle were found to lead to either a vicious cycle or virtuous one. A virtuous cycle can begin with any of the three previously mentioned points, such as healthy dietary practice or exercising. If an individual was to start with any of the three healthy lifestyle choices, then dopamine levels would increase, leading to positive reinforcement, promoting mental wellbeing along with more motivation to improve overall healthiness. These acts lead to less mental distress and the loop continues. Thus, through enactment of one aspect of healthy living, reinforcement of the others is achieved.

Vicious cycles consist of negative reinforcement. When one of these points is not enacted, such as not exercising, or not eating well, then there is a lack of motivation to carry out other similar acts. Mental distress becomes a characteristic of this cycle. However, researchers found these cycles are only existent with young adults, not mature adults. In mature adults, mental well-being does not significantly impact exercise or healthy dietary practices. In that way, there is no correlation between the healthy lifestyle choices and mental well-being. Healthy diet, however, was found to promote healthy dietary practices, mental well-being, and exercise in mature adults, but there is no other positive reinforcement leading to a loop.

In comparison with these mature adults, young adults have different correlations with different practices and diet. Exercising more than three times a week decreases mental distress. Eating fast food more than three times a week and eating meat less than three times a week, both negatively affect mood. Foods and activities that increase neurotransmitter precursors and their overall concentration, to help promote decreased mental distress. Hence, young adults are likely to be more sensitive to low meat as well as exercise, and will have more negative reactions to stress and emotional situations.

In the study, mature adults were less sensitive to daily stresses and negative events. There was also no significant correlation between exercise and increased motivation to continue the positive reinforcement loop. Similarly, eating more fruits and foods high in antioxidants can lead to a more positive mental state in mature adults, whereas drinking coffee, skipping breakfast, and eating low carbs can actually have a negative effect on mood for people in this age range.

This study demonstrates you may think that what you eat affects you the same way, or has set benefits or downfalls, but depending on your age, these foods are affecting you differently. So when they say "you are what you eat," it truly depends on your age.

Cancer in Action

BY NATALIA CHAVEZ, CELL AND MOLECULAR BIOLOGY, 2021

DESIGN BY KYLA VIGDOR, DESIGN, 2021

Cancer is no stranger to society. In fact, nearly 40 percent of people will receive a cancer diagnosis someday, leaving the rest of us to witness its consequences first-hand. Thankfully, with the help of new drug developments and medical procedures, doctors and scientists have been able to weaken, if not arrest, the proliferation of this crippling disease. From 2004 to 2013, the overall cancer death rate in the United States fell by 13 percent and it continues to decline as the years go by. These statistics certainly show improvement, but to increase cancer awareness and improve upon oncology's successes, it is important to understand what makes cancer so dangerous.

Most cells are alike in that they undergo a process known as cell division through mitosis or meiosis. Each normal, functioning cell is designated to a certain function in the organism depending on where it is situated in the body. These cells are responsible for keeping the organism alive by participating in an ongoing cycle that divides and replaces precedent, worn-out cells. More importantly, a well-behaved cell can completely arrest the cell division process in order to limit the number of cells in a particular area. Once it pauses the cell cycle, it takes the opportunity to repair errors after routine checkpoints as a means of avoiding the accumulation of mutations. Unfortunately, cancer cells do not possess these regulatory mechanisms.

> "The essence of cancer's threat lies primarily in its motion: how quickly and how readily it spreads to vital parts of the human body."

When searching for signs of cancer growth in the body, one may come across a group of abnormal-looking cells that seem like they have no place to go but on top of one another. This is because cancer cells continue to divide by ignoring cell cycle signals that tell them to stop growing. Cancer's behavior, then, would be much like that of a stubborn teenager trying to rebel against his parents. What makes the situation even worse, however, is the fact that–unlike normal cells–cancer cells are either unrepairable or do not undergo apoptosis (cell death) at some point in their treacherous lives, leaving them to take the place of healthy, normally-functioning cells.

The essence of cancer's threat lies primarily in its motion: how quickly and how readily it spreads to vital parts of the human body. This problem arises when cancerous cells begin to move from their original growth site to other locations. Another word for this kind of motion is metastasis, and it is primarily associated with the spread of malignant cancer cells. While normal cells associated with stationary organs tend to stay where they belong, cancer cells can travel via the bloodstream and lymphatic system. This is because they lack proteins called adhesion molecules. These proteins are what cause normal cells to have "stickiness," allowing them to adhere to each other instead of straying away from their primary regions. Since cancer cells do not have this ability, they are more susceptible to moving to alternate locations, where they settle and create more and more colonies of abnormal cells. On the other hand, normal cells that are granted permission to flow through the bloodstream, such as lymphocytes, have much more regulated and controlled tasks compared to cancer cells. Whereas these cells only travel along the bloodstream to specific cell surface signals, cancer cells roam around of their own accord. This characteristic is what makes cancer fatal, particularly when its cells start to proliferate uncontrollably in areas where vital organs reside. Once metastasis occurs, cancer cells are in multiple parts of the body, making treatment more difficult and thus quickening the progression of the disease.

For decades, scientists have made it their duty to block cancer pathways by searching for certain metastasizing checkpoints and signals to stop their migration. So far, the information discovered by researchers regarding cancer cells and how they move involves a set of mutant proteins called oncogenes. Oncogenes, in short, cause cancer cells to multiply uncontrollably and play a huge role in promoting metastasis. A key component of these proteins is that they are the result of mutations. Prior to becoming oncogenes, they were proto-oncogenes, which are genes that normally help and control the growth of cells. However, when a proto-oncogene mutates or when there are too many copies of it, the cell is permanently activated and starts to grow out of control, eventually leading to cancer.

With extensive knowledge of oncogenes, scientists have finally found out how some of these genes and their related signals lead to the dysregulation of normal cell processes and the proliferation of cancer cells. How the oncogene specifically directs the metastasis of a cancer cell remains fairly uncertain, but an amazing discovery by Deputy Director of the UH Cancer Center Dr. Joe W. Ramos has changed how scientists

approach cancer cells and their invasive behavior. With the help of his collaborators, Ramos found that oncogenes activate a protein called RSK2 that is essential for cancer cell metastasis. Additionally, they discovered that RSK2 creates a "signaling hub" involving the proteins LARG and RhoA. These proteins activate and excite this signaling hub, resulting in the movement of cancer cells to other parts of the body.

> "By revealing the main operator for the motility of cancer cells, [the researchers] may allow scientists to find more precise drug targets to prevent metastasis."

What Ramos and his team uncovered is not only useful, but revolutionary, to the world of science and oncology. By revealing the main operator for the motility of cancer cells, they may allow scientists to find more precise drug targets to prevent metastasis. Furthermore, according to Ramos himself, this research may also lead to "new therapeutic opportunities for brain tumors, melanoma, and breast cancer" as well as for other fatal cancerous diseases. With this critical information, published in *Proceedings of the National Academy of Sciences* (PNAS), we can expect better and more direct cures for destroying cancer altogether, specifically as it starts to metastasize. Since cell motility is such a dynamic and complex process, the fact that scientists can now directly identify RSK2 is essential for the future's promise of a world without cancer. Discoveries like these are what keep our hopes beaming. Indeed, for instead of asking whether there is a cure for cancer, we can now focus on when and how quickly we will find it.

PNAS (2018). DOI: 10.1073/pnas.1708584115.

One FLU Over the Cuckoo's Nest

BY HUGH SHIRLEY, BIOCHEMISTRY, 2019
DESIGN BY JAMES GOULART, CHEMISTRY, 2021

Like clockwork, the yearly flu virus sweeps across the United States in a predictable fashion. Scientists around the world work year-round to identify what strains the annual vaccine should protect. This year vaccines are potentially ineffective against viral strains, leading to a difficult flu season. To get to the heart of this year's poor vaccine and how the flu moves around the world, let's start with the virus itself.

Influenza viruses are part of a class of RNA viruses with seven different subtypes. Only three of these spread in humans - Influenzas A, B, and C. Of these, type A is the most virulent. Influenza A rapidly undergoes antigenic drift, mutating the proteins on the viral surface that allow antibodies to recognize it as an intruder. These mutations happen at a rate of about one mutation per genome per replication, eventually leading to the body's immune system no longer being able to recognize the strain. The viral surface proteins, hemagglutinin, H, or HA, and neuraminidase, N, or NA, are what researchers refer to when they name the flu H1N1 or H3N2. Year round, health organizations look for the current circulating flu viruses so that "viral antigens included in influenza vaccines are routinely updated in an attempt to avoid antigenic mismatches". This year, the vaccine includes antibodies protecting against H1N1, H3N2, and Influenza B viruses.

Flu vaccines provide the immune system the opportunity to keep up with antigenic drift, but that does not seem to be the case this year. The flu moves around the globe in two separate flu seasons, one in the Northern Hemisphere, and one in the Southern Hemisphere. The Australian flu season, from April to October, clues scientists at the Centers for Disease Control (CDC) and other health organizations on what to expect for flu season in the US, from October to April. If our flu season looks anything like Australia's, it will be rough.

Australia's flu season saw more than twice the usual confirmed influenza cases and an increase in deaths that corresponded with the increased infection rate, according to an Australian Influenza Surveillance Report. The vaccine used in the US is the same as the one used in Australia, as health officials use the predominate Australian strains to predict what strains will move through the US population. The Australian vaccine's average effectiveness rate against the H3N2 virus, seen prominently through the US, was 10 percent, compared to 57 and 33 percent for Influenza B and H1N1, the other two strains the vaccine protects against.

There are several theories as to why this year's flu season could be especially impactful according to Dr. Samuel Scarpino, Professor of Marine & Environmental Sciences in the Emergent Epidemics Lab at Northeastern University. According to Scarpino, the predominant theory is that "as a result of growing vaccines in chicken eggs, the virus picks up mutations, and those mutations change the antigens on the surface." Tests comparing vaccines cultured in chicken ova and those cultured in different animal tissues have shown that the non-ova vaccines are more effective at preventing H3N2 infection. These tissue-propagated vaccines were not available during the Australian flu season so there is no population level data on the new vaccine. Now that the vaccine is available in the US, researchers can gather that population level data. H3N2 viruses also seem to be more virulent than other strains of Influenza A. "Influenza seasons that are dominated by the H3N2 version of the virus tend to be more severe" Scarpino noted. It's theorized that people from their late teens to mid-forties were exposed to H1N1 strains more frequently in their youth and are more susceptible to H3N2 strains, which is causing the increased morbidity and mortality rates in flu seasons were H3N2 strains are most prominent.

Even though the primary vaccine is only 10 percent effective against the H3N2 virus, health officials recommend getting the shot, because the vaccine is still highly effective against both the Influenza B and H1N1 strains. Vaccinated people also have lower morbidity if they do eventually catch the flu, meaning fewer days in bed according to Scarpino.

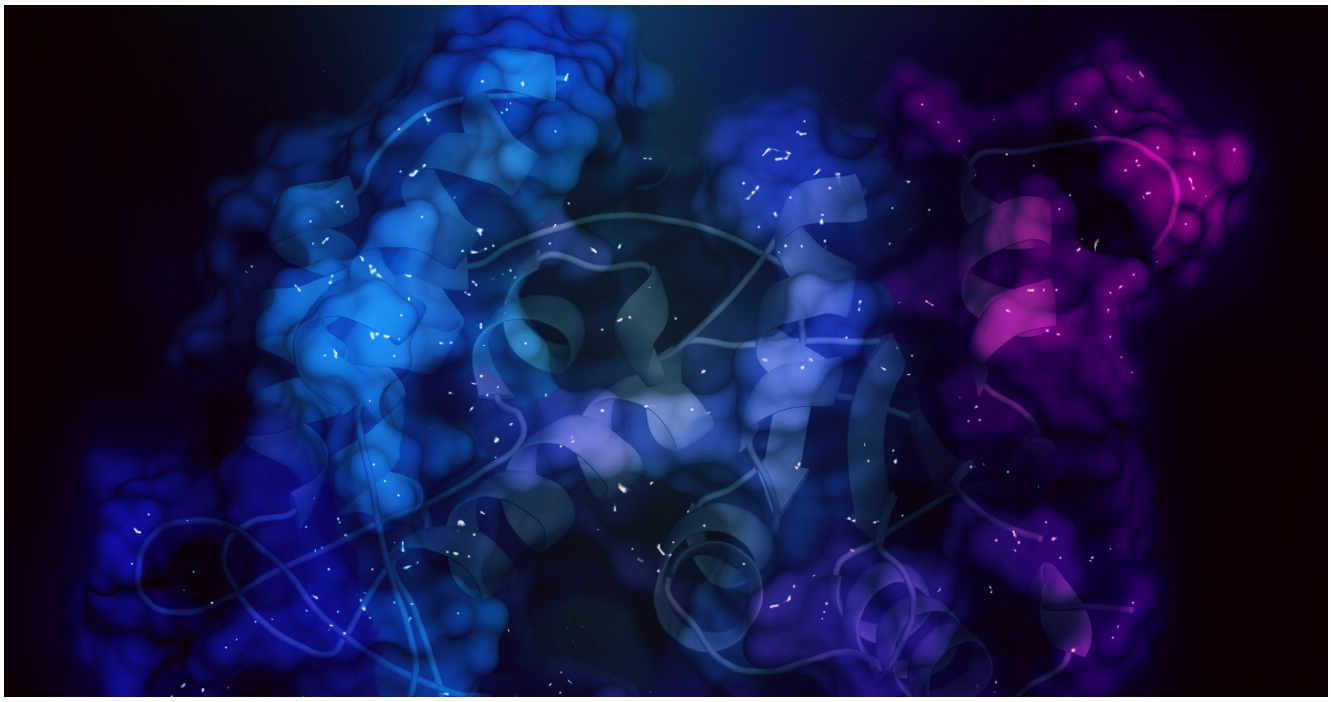
The flu can be a debilitating illness and its impact on civilization should not be forgotten; The possibility of a Spanish Flu level pandemic, scaled up to the modern world's globalized proportions, should not be ignored. As research on how to best prepare for subsequent flu seasons continues, protecting yourself in the best way possible should be an annual goal. Even though the vaccine this year might not be as effective against viral strains as years past, it should not be dismissed and is well worth the slight pinch that it takes.

A Run-and-Tumble Process

Scientists make new discoveries about the movement of enzymes in a substrate

BY MALCOLM SHUMEL, BIOENGINEERING, 2021

DESIGN BY FIONA GRIDLELY, COMPUTER SCIENCE AND DESIGN, 2021



Enzymes drive forward many important reactions in the human body. To accomplish this, the reactants, or substrate, bump into the enzyme, where they react. What scientists don't know is how the enzymes and substrate meet.

A team led at Center for Soft and Living Matter, within the Institute for Basic Science (IBS, South Korea) led by Steve Granik examined the issue and found a surprising result; they published in *Proceedings of the National Academy of Sciences (PNAS)* that enzymes in a substrate gradient move toward the area of lower concentration. The study described this motion as "a 'run-and-tumble' process analogous to that performed by swimming microorganisms, executed in this situation by molecules that lack the decision-making machinery of microorganisms."

The run-and-tumble process is a relatively simple one. A microorganism takes a pace in a certain direction, turns randomly, and takes another pace. In a low nutrient environs, this pace will be a longer one, and in a high nutrient environs, the pace will be a shorter one. The result is that while the movement of a microorganism may appear random, it is biased to stay in an are with higher amounts of nutrients. It is therefore said to exhibit "chemotaxis", or a tendency to travel toward a chemical.

Enzymes, according to this study, exhibit "antichemotaxis", that is, they have a tendency to travel away from a chemical. When interpreting this result, it's important to remember that enzymes are not nearly complex enough to possess the decision-making capabilities that microorganisms have. The team theorized that enzyme-substrate reaction "enhanced enzyme diffusivity". Going back to the run-and tumble process, this means that the length of the pace is increased. This fact causes enzymes, somewhat inadvertently, to move down the substrate gradient.

To measure these paces, the team had to observe the enzymes on the scale of 50 nanometers. To do this, they used the technique of STED-FCS, which stands for stimulated emission-depletion fluorescence correlation spectroscopy.

In FCS, target molecules are first tagged with a fluorescent marker, a molecule with the properties that it binds to the target and it "lights up" when hit with a laser. The target is then allowed to diffuse through a laser, and the resulting fluorescence and its fluctuations are recorded and interpreted as speed and direction of the target. The innovation in this experiment was to use a STED microscopy to excite the markers. STED allows for a more focused laser beam, and therefore the observation of smaller things, by surrounding the laser with another low-power laser, which prevents the molecules it hits from reflecting anything. The result is that the team was able to observe enzymes on a smaller scale than ever before.

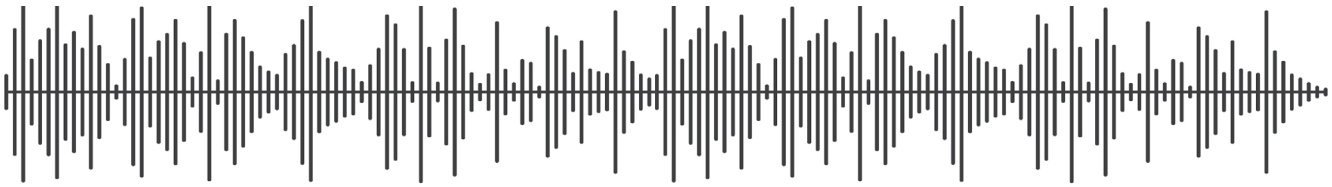
This study only looked at one enzyme in one substrate gradient. In the future the team hopes to apply STED-FCS to more complex systems to analyze enzyme behavior in more true to life scenarios.

The Sound of Music

What's all the noise on binaural beats?

BY ADITI PEYUSH, BEHAVIORAL NEUROSCIENCE, 2021

DESIGN BY IRINA PYATAEVA, BIOENGINEERING, 2020



For years, binaural beats have been marketed as "music for your brain." Listening to different audio frequencies simultaneously is thought to improve concentration during studying, aid in meditation, increase creativity, and provide energy. However, many people don't understand how the brain is actually affected by the presentation of these sound waves. So before you reach for your headphones, do binaural beats actually work?

In 1924, German psychiatrist Hans Berger used his invention, the electroencephalogram (EEG) to study the behavior of the human brain. He found that different sound and sight stimuli produce different responses in the brain. These "brain waves" are formed when our neurons interact to produce neural oscillations, or rhythmic neural activity that originates in the central nervous system when the peripheral nervous system perceives outside stimuli.

Types of Brain Waves

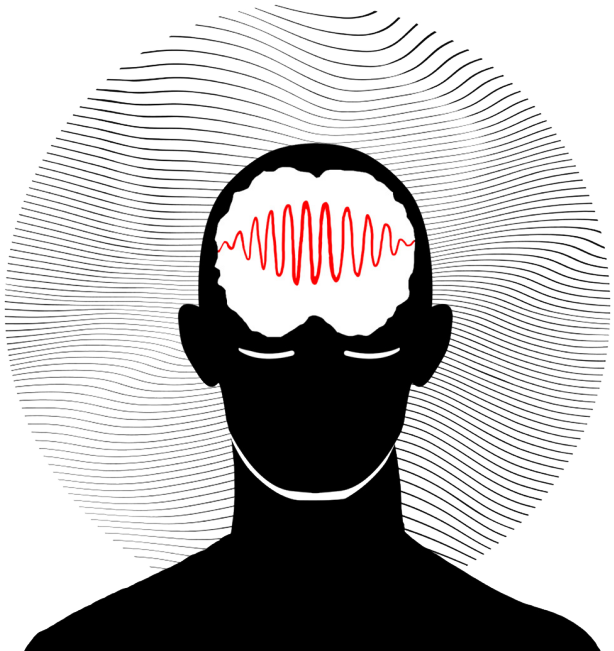
Name	Frequency (Hz)	Correlation
Delta Waves	0.5 - 3	A state of deep sleep
Theta Waves	3 - 8	Drowsiness and meditation
Alpha Waves	8 - 12	Brain's resting state or relaxation
Beta Waves	12 – 38	Normal consciousness
Gamma Waves	38 - 42	Rapid information relay and focus

These resulting brainwaves play a role in our actions as well as in our emotional states. There are five categories of brainwaves, each of which has a greater frequency than the next. The table above illustrates each type of brainwave and its impact.

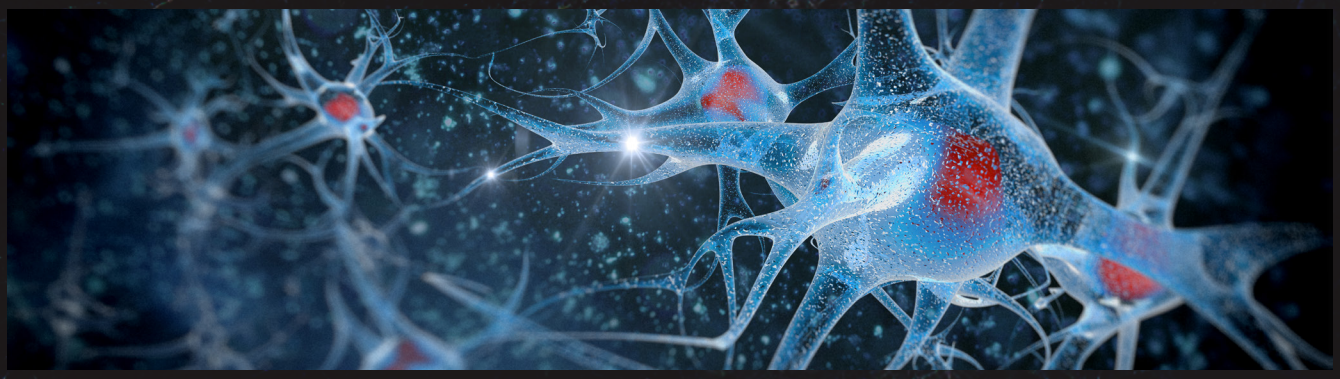
Brain activity can also be influenced by our perception of sound waves. When two audio frequencies shaped like sine waves (yes, the one from math class) with frequencies lower than 1500 Hz are presented dichotically, or in both ears, their overlap creates the illusion of a third wave: the binaural beat. Just like brainwaves, binaural beats also vary in frequency depending on purpose; for instance, if an audio wave of 400 Hz is presented in your left ear while an audio wave of 440 Hz is presented in your right ear, the difference between those two waves (40 Hz) is the frequency of the binaural beat. Different types of binaural beats can be aimed toward "audio-visual entrainment," which is the use of frequencies to induce different patterns of brainwave activity.

While there is currently no study that confirms how the third wave, or binaural beat, is formed, there is research to support its possible benefits. One study published in 1998 in the journal Physiology and Behavior showed that binaural beats with beta or gamma frequencies yielded positive emotional states and greater cognitive performance. Another study published in Frontiers in Human Neuroscience in 2013 showed that binaural beats affect divergent–or creative thinking–tasks, but not convergent–or straight-forward thinking–tasks. Yet, a study published in 2015 in Frontiers in Psychology showed a positive correlation between the stimulation of gamma waves and long-term memory capacity, meaning that listening to a binaural beat of around 40 Hz for an extended period of time may result in a higher retention of information.

So, what's the verdict? Binaural beats have been shown to be effective in activities that involve creating thinking. However, scientists have not yet truly concluded whether binaural beats have an impact on our cognitive ability. More research is definitely needed to fully understand how this third wave can improve our day-to-day lives. But if you want to test the waters, Spotify, YouTube, and MyNoise.net have a plethora of beats to experiment with. Try it out for yourself and see if it works for you!



Motor Memories and Senses



BY ALEXANDRA JACULLO, BEHAVIORAL NEUROSCIENCE, 2021

DESIGN BY IRINA PYATAEVA, BIOENGINEERING, 2020

Every second of every day entails sensory stimulation in a variety of forms that the brain and body must detect, make sense of, and respond to. This involves many intricate networks, which are most fundamentally designated as the sensory and motor systems. Behind the scenes, these two systems participate in extensive communication to allow for efficient functioning in an ever-changing environment.

An intriguing illustration of this interaction is known as auditory-motor resonance, or AMR, in which external sensory stimuli, such as hearing or seeing certain actions, can activate internal motor regions. This association occurs in the absence of actual motor output, meaning that areas of the brain involved in movement are stimulated but the body does not exhibit any physical movement.

> "Research has shown that trained musicians and novice participants alike display activation in key motor portions of the brain while listening to different musical stimuli."

The basis of AMR in humans was pioneered by discoveries of mirror neurons in animal models. Macaque monkeys were found to have these special motor neurons that are activated both when performing an action and when seeing that same action being performed. Research involving songbirds also revealed the presence of mirror neurons equivalent to those of Macaques, and indicated that mirror neurons are sensitive to both visual and auditory stimuli modalities. While researchers have yet to prove the precise existence of human mirror neurons, these breakthroughs helped to establish what is currently believed to be a general mirror system in humans.

A significant amount of understanding of this AMR mirroring system in humans has come from studies that employ technologies like functional MRI (fMRI), EEG, and transcranial magnetic stimulation (TMS) to measure neural activity in association with sensory stimuli. Such research has shown that trained musicians and novice participants alike display activation in key motor portions of the brain while listening to different musical stimuli. Additionally, numerous research endeavors have demonstrated how observing certain movements, from basic hand grasping to elaborate dance routines, activates commensurate motor brain regions and, in many cases, also stimulates the distinct muscles involved in executing the observed action. There is even indication of similar kinds of purportedly AMR-derived responses in infants less than a year old.

As always in science, there are differing opinions as to the "big picture" reason behind the existence of AMR. While many believe that the human mirroring system is purely a product of associative learning and experience, others argue that it is determined by genetic evolution and serves as an ecological advantage, specifically in social cognitive and communication capabilities.

It has been proposed that AMR affords advantages in distinguishing known sensory information in the context of unfamiliar or disrupted environments. For example, consider a relatable scenario in which you are trying to listen to another person who is speaking to you in a noisy room. The most common instinct is to watch the movement of the person's lips to try to better understand what they are saying. Mimicking this scenario, studies have shown evidence of muscle activation in the lips, as well as the tongue, of the listener while the speaker is talking; this stimulation of corresponding areas of the mouth is believed to aid speech comprehension in instances of external disturbances.

Given the lack of a definitive explanation of AMR development in humans, there are quite a few theories as to the underlying mechanism that drives this phenomenon. Some theories broadly postulate that AMR is dependent on neural connectivity accompanying the association of sensory and motor information that occurs during learning. Meanwhile, other theories reject this simplicity and approach AMR from a more complex perspective, attempting to account for different limitations of the system involving feedback and integration delays. As a means of reconciling these paradigms and acknowledging their independent validities, current standard theories recognize the probability of an internal mapping mechanism that incorporates both approaches to refine interdependent sensorimotor connections. Future directions of AMR research are focused on establishing a more certain understanding of the mechanism of this system, as well as discovering and localizing specific human mirror neurons.

A Leap Is Worth a Thousand Words

Communicating social justice issues through dance

BY GWENDOLYN SCHANKER, JOURNALISM AND BIOLOGY, 2018

DESIGN BY NABEEL SHERAZI, APPLIED PHYSICS, 2020

On Monday, January 15, 2018, the Isabella Stewart Gardner Museum held a dynamic, all-day celebration of Martin Luther King Jr. Day. Among the participants were Marsha Parrilla and the other members of her Boston-based dance company, Danza Orgánica. Through their 40-minute performance, "Melaza," which they performed for an audience of over two hundred, Parrilla and her fellow dancers illustrated the colonial relationship between the U.S. and Puerto Rico. Their goal? To promote social change.

Parrilla, a Puerto Rico native who migrated to the U.S. when she was 22 years old, founded Danza Orgánica in 2007. Parrilla holds a master's degree in dance education from New York University and is a strong believer in the power of storytelling through dance.

"I think the body stores a lot of information that we're not conscious of," she said. "I think verbally some things get blocked and the body is dying to get those things out."

Research on nonverbal communication shows that Parrilla is right. According to studies conducted in the 1960s by Dr. Albert Mehrabian on the importance of nonverbal communication, only seven percent of communication when speaking comes from the words spoken, while 38 percent comes from vocal tone and 55 percent from body language. This formula does not apply to every situation, but it's clear that nonverbal communication plays an important role in conveying messages. For that reason, a medium like dance lends itself well to Parrilla's mission of using movement to illustrate issues like racism, classism, and socioeconomic struggle.

> "I think verbally some things get blocked and the body is dying to get those things out."
>
> *– Marsha Parrilla*

There are three commonly referenced types of nonverbal communication, all of which are embodied in Parrilla's choreography. The first is kinesics, which refers to general bodily movement as well as facial movements and eye contact. In "Melaza," many of the dancers' movements incorporate a wavelike motion in the spine. This represents the importance of flexibility when it comes to surviving difficult situations – like the challenges of migrating from Puerto Rico to the U.S. or the realities of life after Hurricane Maria – as well as the flexible strength that allowed Puerto Rico's palm trees to survive the hurricane.

The second type of nonverbal communication is haptics, which refers to communication through touch. Haptics play a particularly important role in Danza Orgánica's performances, as the dancers hug and push one another aside in turn to represent different aspects of the complex relationship between the U.S. and Puerto Rico. Parrilla's use of touch in her choreography is directly related to her use of the third type of nonverbal communication, proxemics, which refers to distance. During many parts of "Melaza," the dancers move in a clump and are standing, sitting, or lying very close together. Like the other aspects of communication in Parrilla's choreography, the dancers' proximity is purposeful, illustrating everything from crowded living conditions at home to the support that family and friends have for one another.

The performance on January 15 was what Parrilla refers to as the "first phase" of "Melaza." Over the next two years, she and her colleagues will continue to work with artists in the U.S. and Puerto Rico to develop the second phase of the performance. Parrilla is also an artist in residence for the city of Boston for 2018. Throughout the year, she'll work with fellow artists, city employees, and community members to explore how art can be used to further local initiatives like climate change and immigration. Parrilla says the latter issue is especially close to her heart.

"When I moved to Boston I noticed it was quite segregated, and it was hard to find my place," she said. "I think it's very exciting to be in a place in my life where one thing that I identified as a problem in the city is now being highlighted by the city as a problem that they want to take on, and I'm part of that."

Vocal actions like impassioned speeches and chanting in protest are usually the first that come to mind when considering how best to communicate social justice issues. However, Danza Orgánica and Marsha Parrilla are proof that verbal communication is certainly not the only, and not always the best, way to get a message across. In some cases, nonverbal communication can be equally or more effective. The use of dance as a tool for promoting social change is worth further examination in a world full of loud voices and increasingly short attention spans.

PHOTO BY GWENDOLYN SCHANKER

The Long-Running *Myths About* Running

BY KATELYN MCCREEDY, HEALTH SCIENCE, 2021
DESIGN BY NABEEL SHERAZI, APPLIED PHYSICS, 2020

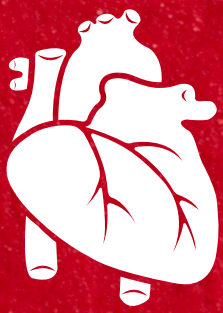
According to a 2013 study from the Center for Disease Control, 80 percent of Americans do not exercise for the recommended 2.5 hours per week. If this wasn't already difficult enough for the average American, conflicting information exists about one of the most common methods: running. Lingering questions about the damage that it can cause to joints makes getting regular exercise even more confusing and daunting.

Sheng-Che Yen, PT, Ph.D., is an assistant professor in Northeastern's Department of Physical Therapy whose lab often uses treadmills in its analysis of locomotion. For those trying to decide between running indoors or outside, Yen offers this advice: "compared with regular running, I would say treadmill running is actually safer." According to Yen, treadmills are not only safer, but in some cases preferable for a host of reasons. For one, it's easier to control the environment and avoid uneven surfaces. In fact, treadmills are becoming increasingly advanced and can even use suspension systems to reduce the impact of running.

> "Compared with regular running, I would say treadmill running is actually safer."
>
> *- Professor Sheng-Che Yen*

There is a subset of Americans, however, who should carefully consider their treadmill use. For example, those training for marathons should opt instead to train outdoors as it better mimics the terrain that they will encounter during the event. Furthermore, anyone who experiences dizziness should also be cautious of treadmill running. When a person is running outside, the environment around them moves as they do. "Your central nervous system expects a visual flow, but on the treadmill, you don't have that," explains Yen. Instead, their peripheral vision sees a static environment, which is disorienting for the brain.

For the many runners who prefer to run outdoors, they can minimize the pressure that they place on their joints with a handful of mathematical calculations. In 2011, researchers at the University of Wisconsin-Madison studied joint pressure on the legs of 45 runners while they ran on treadmills. They found that when the runners increased their cadence - the number of steps that they take per minute - by just 5 to 10 percent, they significantly reduced the pressure that they put on their joints. Cadence can be calculated by running at a natural pace for one minute and counting the number of steps taken on one foot and then by multiplying that amount by two to account for both legs. "People tend to have a larger cadence on the treadmill, meaning the step rate is increased while step length is reduced," Yen said. Essentially, runners should aim to take shorter strides more often to reduce the impact on their joints, which the treadmill aids in doing.



Another mathematical consideration for runners is the Karvonen Formula, which calculates target heart rate. Dr. M.J. Karvonen is considered the founder of cardiovascular epidemiology. According to Karvonen's research, it is best to stay between 60 to 75 percent of your maximum heart rate. This is calculated by subtracting individual age from 220. For example, the target heart rate range for an 18-year-old would be between 121 and 152 beats per minute. In addition, fitness tracking watches can monitor heart rate and help runners stay within their ideal heart rate range.

KARVONEN'S FORMULA

$(220 - \text{Age}) \times 0.75 \rightarrow \text{Upper Bound}$

$(220 - \text{Age}) \times 0.60 \rightarrow \text{Lower Bound}$

Research in the physical therapy field will continue to expand our understanding of how and where to best run. In the meantime, a few calculations before heading out could help more proficient runners make great strides. As for the millions of Americans for whom weekly exercise is a struggle, scientific research and technological advancements will continue to make running an increasingly accessible option.

The Cost of a Kick in the Head

A look into CTE

BY SAGE WESENBERG, BIOLOGY AND JOURNALISM, 2019

DESIGN BY VICTORIA PAJAK, BEHAVIORAL NEUROSCIENCE, 2021

It's nearly impossible to imagine having your head hit hundreds of thousands of times over the course of your lifetime, but for many football players, military veterans, and boxers - that is reality.

Chronic traumatic encephalopathy (CTE) is a degenerative brain disease caused by repetitive brain trauma over a period of many years. Contrary to popular belief, this brain trauma is more often comprised of patients who have had hundreds of subconcussive impacts on their head, not full concussions. Symptoms are slow-progressing and may not present themselves for anywhere from eight to 30 years post-sport activity.

Because this disease affects the brain, symptoms show in four different categories: behavioral, cognitive, mood, and motor control. They may include changes like impulsiveness, aggression, irritability, impaired memory, muscle weakness, inability to concentrate, and can eventually lead to dementia.

CTE has become well-known due to football player Aaron Hernandez, the 27-year-old New England Patriots tight end who committed suicide in jail in September 2017 while serving time for the murder of his friend, semi-professional football player Odin Lloyd. After Hernandez' death, researchers were able to identify Stage 3 CTE through brain tissue analysis, the worst case ever seen in someone of his age. The damage was equivalent to a CTE patient in their 60s - parts of his brain were atrophied, others severely damaged and shrunken.

But how does this disease actually work?

In the brain, we heavily rely on the complex nervous system to help us react and interpret everything around us. Brain cells called neurons send signals throughout the brain through electrical stimulation down their axons to other nearby neurons. Axons give each neuron its length, as long and spindly pieces that help reach different parts of the brain. However, because of their structure, they are also very fragile to injuries like concussions. Damaged axons make it more difficult for the brain to send messages and distribute chemicals.

Every nerve cell has microtubules running the length of the cell, that can help axons pass on these messages and chemicals. Their structure is supported by the Tau protein, which sticks on to the outside of the microtubules. In healthy brains, this is an efficient system, with all components working well together. But in brains that have sustained many head injuries, the Tau protein becomes the root of the problem.

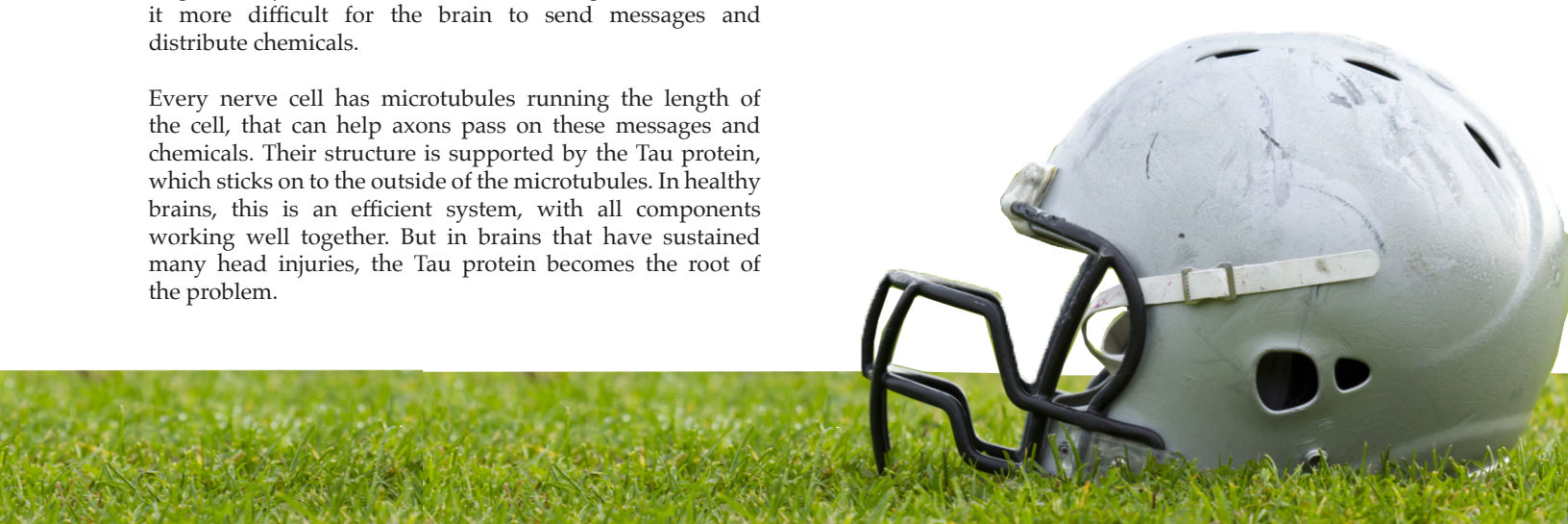
Microtubules are much weaker than the axons, so they are even more vulnerable to both concussions and smaller head injuries that would not damage the axons themselves. As microtubules break down due to these injuries, the Tau proteins begin to float around inside the cell, clumping together and phosphorylating - a chemical process that changes the structure of proteins.

As these clumps form, they begin spreading around the brain and can continue to grow abnormally. This spread of Tau takes many years for enough brain tissue to be affected to alter its function and present symptoms.

There is still much we don't know about why this disease does not happen to everyone or when it starts developing in the brain. Because it is so slow to develop, it is very difficult to diagnose before death, since it requires analysis of many slices of the brain. However, because of increased awareness about CTE, there is more research occurring and hopefully developments to be made.

In 2005, the Boston University School of Medicine formed the VA-BU-CLF Brain Bank with the Veteran's Association and the Concussion Legacy Foundation as a research center for CTE, after Pittsburgh Steeler Mike Webster was the first American football player to be found with the disease. They have now studied over 400 brains, 250 of which have been found to have CTE. In 2015, the Brain Bank collaborated with the National Institutes of Health (NIH) to help increase the ability to accurately diagnose CTE by publishing diagnostic criteria for the disease.

There are still many questions to be answered, including more about how the disease actually works, and others on how to diagnose CTE in living people, but ideally as we learn more about this complicated disease, we can either develop better protective gear and technology to prevent and predict damage, or perhaps less people will play these high impact sports which could inevitably lead to their demise.



How Olympians Train Their Brains

BY KATRINA CHEN, PSYCHOLOGY, 2021

DESIGN BY VICTORIA PAJAK, BEHAVIORAL NEUROSCIENCE, 2021

Shooting that perfect three-pointer, sticking that landing of the backflip, perfecting that ski jump. All of these take extreme skill, focus, and for many Olympians – mental visualization. Prior to competition, many athletes use psychological techniques to enhance their concentration and performance.

By rehearsing a detailed mental image of the desired outcome, athletes can improve physical performance in their sport. Negative subliminal emotions of fear and anxiety often overcome athletes under stress and lead to athletic mistakes and failures. Repeated visualizations can train the subconscious mind to guide the body during the performance. There are two main theories that are used to explain this phenomenon.

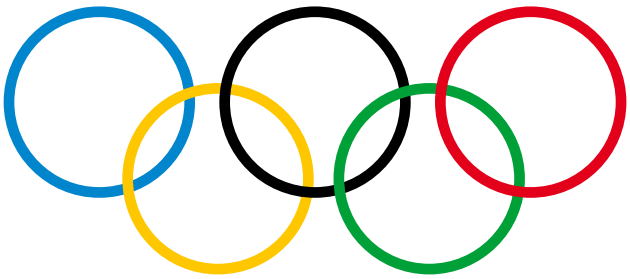
> "The more vivid the mental image, the more effective the results and the stronger the athlete performs under pressure."

The psychoneuromuscular theory states that by imagining movements, the brain subconsciously creates neuromuscular patterns similar to those constructed during physical movement. When movements are visualized, the neuromuscular system is exercised and neurons in the brain are fired to signal the muscles. All of this is done without the athlete actually moving. So, when a tennis player like Serena Williams visualizes a serve, the electrical activity in her brain mimics the electrical activity in her brain when she is actually serving the ball.

Similarly, the symbolic learning theory suggests that mental imagery creates a blueprint for the upcoming motions. This blueprint contains the goals, motion sequence, and solutions needed for the performance. The more the mental image is visualized, the stronger the blueprint, and therefore the stronger the performance. By practicing visualization for around 10 minutes a day and five times a week, both during off season and right before competition, amateur and elite athletes alike can significantly improve their performance in sports.

The more vivid the mental image, the more effective the results and the stronger the athlete performs under pressure. In visualizing the performance, athletes can either use the internal perspective – which involves looking out of your body as if you are performing the sport – or the external perspective, which is visualizing your body as if you are watching yourself from a camera. Most athletes choose to visualize using the internal perspective, but both perspectives are equally effective.

Imagery is the key competent to sport visualization, but for Olympic skier Emily Cook, her pre-competition routine goes beyond visualization. "You have to smell it," Cook said in an interview for the *New York Times* in 2014. "You have to hear it. You have to feel it, everything."



By imagining the smell of the snow, the roar of the crowd, and her muscles firing, Cook increases her focus and confidence while executing high-skilled, freestyle-skiing sequences. The most effective mental visualization encompasses multiple senses, not just the visual sense. Incorporating visual, aural, physical, and emotional thoughts that occur during competition allows an athlete to most effectively improve all aspects of their performance.

More advanced visualization techniques are used by elite athletes during their training and before competition. First, an athlete will slow down the speed of the mental image and ensure the perfection of each motion. Then, they will slowly increase the speed of the visualization. This technique improves specific skills in their performance and ensures that athletes do not overlook key details in their performance. Additionally, athletes can make use of emotions to fuel their performance. To establish confident and strong performances, athletes can create powerful emotions through visualization. By intensifying and speeding up their visualization, athletes can help their subconscious brain, leading to a more powerful and successful performance.

For example, a runner like Usain Bolt trying to improve his sprinting times can use visualization to run faster, but this is not possible without the use of emotions. He must visualize both the image of himself running and the positive emotions felt during his run. These emotions may include excitement, pride, and a sense of power. With the combination of these positive emotions and a sped-up image of himself running powerfully, Usain Bolt could significantly improve his performance.

Psychology and the unconscious mind play an imperative role in athletic performance that often goes neglected by athletes and coaches. The positive outcome of mental visualizations has proven to assist athletes in their confidence and performance. Perhaps before your next gymnastics meet, volleyball tournament, or dance competition, try visualizing your motions and imagining all your senses – you may just be shocked by the outcome.

IN THE NICK OF TIME: ENGINEERING THE TWO-HOUR MARATHON

BY RAFI RAZZAQUE, ENVIRONMENTAL SCIENCE, 2019
DESIGN BY YECHAN YANG, PSYCHOLOGY AND CHEMISTRY, 2022

The term "marathon" dates back to the legend of Philippides, the Greek messenger who supposedly ran from the battlefield of Marathon to Athens to announce the defeat of invading Persians in 490 BC. Over 2500 years later, his heroic efforts are replicated by about 500,000 every year in the US; for many though, merely replicating this Herculean effort is not enough. An elite few are looking to leave their own mark on history: by being the first to break the two-hour mark in a marathon.

> "The marathon as an event came to be in the 1896 Olympics, where organizers looked to evoke Greek history and mythology."

The marathon as an event came to be in the 1896 Olympics, where organizers looked to evoke Greek history and mythology; the famous distance of 26.2 miles or 42.195 kilometers was not finalized until 1924, by the International Amateur Athletic Federation, with the record time that year being 2:35:59. The current officially recognized record is 2:02:57, run by Dennis Kimetto, in the 2014 Berlin Marathon. Only twice since 1924 has a marathon world record been bested by over three at a time, meaning any efforts to undercut the two-hour mark will most likely be incremental hacks as new record times are achieved and broken.

Despite the uphill battle against time, both science and business are optimistic at the opportunity to face down this seemingly insurmountable challenge. A 1991 paper suggests that marathon speed is governed by O_2 uptake (VO_2 max), lactate threshold (the point at which lactate acid accretes exponentially in humans) and running economy; they predict someone with a lactate threshold of 85 percent and a VO_2 maximum of 84 mL/kg per minute and "exceptional running economy" could feasibly complete a marathon in 1:57:48. Breaking this down biologically, elite male runners have been observed to have a VO_2 max of up to 85 mL/kg, but rarely above; lactate thresholds are based off of VO_2 max values, and can hit levels of up to 80-85 percent of VO_2 in elite runners.

Because elite runners are capable of building up their biological tolerances through extreme fitness training, the 'efficiency' of their running becomes a new limiting factor in the way of achieving a two-hour marathon. After all, 45 percent of power produced from the legs actually drives runners forward. Improving running form to reduce this inefficiency is one possibility; improving the distance driven by each stride is another, with shoe companies introducing lighter shoes with more spring to them to improve a runner's stride. The layout of a course, and elevation relative to sea level and weather conditions can also impact runners.

Recently, several commercialized efforts have stepped in to sponsor this achievement; Nike's Breaking2 project coming the closest, with a 2:00:25 time by runner Eliud Kipchoge in 2017 that was not recognized by the IAAF. Additionally, Adidas and sports professor Yannis Pitsiladis also intend on backing independent efforts to break the two-hour mark as well.

These commercialized efforts will probably require incredible planning to optimize conditions for their represented athletes. For Nike's televised event, they intentionally ran the race on the flat and broad cornered Mugello racing circuit in Italy, started the race at 5:45am, with a pace car and several pace runners moving in formation to limit wind resistance. In addition to this aerodynamic trickery, the athletes were handed replenishments from scientists on bikes to minimize time loss. The last two factors prevented the IAAF from certifying the effort as an official record, but Nike's spectacular efforts with Eliud only to fall short by less than a second a mile indicate that one day, we could get to the magical two-hour mark.

And then what? Who knows. But the notion of challenging ourselves to places unknown predates Philippides' mythical run, and technological advances and healthy competition suggest this feat is not a matter of when, but how and with who. Stay tuned, mankind.

Journal of Applied Physiology (1991). DOI: 10.1152/jappl.1991.70.2.683.

The Real Reason Behind Your Runner's High

BY JULIA WALL, CELL AND MOLECULAR BIOLOGY, 2021

DESIGN BY SILVIA DIAZ, DESIGN, 2021

During a difficult workout, runners enter a state of euphoria that evolved from our ancestor's need to catch their next meal. The body's endocrine system would boost their pain tolerance while chasing prey, allowing them to capture exhausted animals. Today, this is referred to as a "runner's high." Since the coinage of the phrase "runner's high," scientists have believed that this phenomenon was solely based on the release of endorphins because they are released in response to physical discomfort. While they are found in the blood at higher concentrations during exercise, endorphins do not fully explain the "runner's high" phenomenon.

For one, endorphins cannot pass through the blood-brain barrier because they are simply too large. Therefore, it is unlikely that there is a correlation between endorphins and experiencing a euphoria after running. In a recent study of mice by German scientist Johannes Fuss, it was found that endocannabinoids, a specific type of neurotransmitter, are also released during exercise. Specifically, it was found that the endocannabinoid anandamide is produced. Any cell in the body can produce endocannabinoids, so an increase in their levels in the blood are mirrored in the brain. This contrasts with endorphins, whose production is limited to the legs. Therefore, anandamide is more likely to be responsible for this experience.

The neurotransmitter behind the high is fondly referred to as the "bliss molecule" because it binds to the same receptors as THC, found in cannabis, does. Both produce a heightened state of happiness and exhibit anti-anxiety and antidepressant properties. Since Fuss's study links a drug-induced high to a runner's high, many competitive runners have begun eating cannabis edibles before a run, despite cannabis being a banned substance in all competitions. This results in an "ultra-high," where the body can be pushed to its limit yet feel relatively little pain. The two variations of "highs" are so similar that they can be combined to promote endurance during running.

Therefore, the next time you hit the gym, give endocannabinoids some credit for making it through the blood-brain barrier and allowing you to resist the incredible pain that accompanies running.

DOI: 10.1073/pnas.1514996112

A Cheetah's Speed

How to achieve nature's fastest acceleration

BY DENNY TRUONG, CHEMICAL ENGINEER, 2020

DESIGN BY SILVIA DIAZ, DESIGN, 2021

The Ferrari 488, a luxury vehicle released on the market in 2016, can reach 60 miles per hour in a mere 3.1 seconds, which puts it on the list of fastest cars by acceleration.

That same Ferrari might seem like an old train when compared to the acceleration and agility of land's fastest animal, the cheetah. This big cat's athleticism is impressive, and they are one of nature's most extraordinary creatures.

Regularly observed to reach upward of 60 miles per hour, the mere fact that a cheetah can achieve this speed without fuel or electricity is astonishing. However, speed is not the cheetah's most striking feature. The unparalleled acceleration and deceleration is truly remarkable. A cheetah has the fastest acceleration recorded – rest to 60 mph is 2.9 seconds. In addition, the cheetah's maximum lateral acceleration – the ability to stop and accelerate in a lateral direction – is a whopping 13 m/s^2. The maximum deceleration – the ability to reduce speed – can be observed at 12 m/s^2. These values are easily superior than the best cars in the industry.

As with other wonderful natural creations, scientists have been looking into the mechanism for acceleration from the perspective of this big cat in an effort to apply it into new innovations. The cheetah's enlarged heart and powerful lungs are equivalent to the engine in a car, and its aerodynamic body shape is similar to the designs of the speediest automobiles on the market. The next assimilation might come from the animal's tail, which is capable of counterbalance against the shift in momentum. This idea is proposed by Dr. Amir Patel, an electrical and robotic engineer at the University of Cape Town. He designed a small, robotic, RV-like structure with a "tail" twice its length. There is data that indicates a tail might help with the acceleration but the experiment was mostly inconclusive. Dr. Patel pointed out that cheetahs have full control and can re-adjust their tails when moving, while the robot cannot. In addition, the flexibility of a cheetah's tail was not taken into account when the robot was programmed. He hopes that this research encourages future studies on the connection between the world's most agile hunter and advancement in motor vehicle technology.

Scotland's New Land Motion Map

BY NATALIE MCGOWAN, BEHAVIORAL NEUROSCIENCE, 2021

DESIGN BY KRISTI BUI, COMPUTER SCIENCE, 2021

Researchers at the University of Nottingham have recently created a land motion map spanning the entire country of Scotland. They did it using Intermittent Small Baseline (ISBAS) Analysis, which uses satellites to detect electromagnetic waves across a certain space. This technique was used to collect data for vertical land motion in Scotland between 2015-2017. The researchers could then visualize the amount of land motion that occurred across the country. Although this technique has been utilized to observe land motion before, this is the first time that it has done so for an entire country.

The land motion captured by these satellites can constitute anything from natural land processes, such as tectonic plate movements, or human processes, such as urban development. In addition, Scotland's biome consists of peatlands, which are characterized by partially biodegraded plant matter and are heavily saturated with water. However, these lands often experience subsidence, or sinking, which is a type of vertical land motion that can be detected by ISBAS.

Thus, this map has potential uses in a variety of settings. For example, this map could be used to more safely implement practices that affect land motion, such as oil and gas production. Industries could ensure that oil and gas extraction is carried out in the safest way possible. Similarly, countries planning to institute hydraulic fracturing (fracking), a method of extracting natural gas from deep rock formations, could benefit by using these maps to ensure that it is carried out in a safe location. Although Scotland has banned fracking, other countries could use a map in such a way to improve the safety of similar practices.

It could also be used to monitor rural areas to detect potential landslides before they happen. Furthermore, civil engineers could monitor areas in which projects are in development to make sure that the construction is not increasing the risk of the land sinking.

Finally, the map gives more insight into risk assessment, which could help it improve policy decisions made by the government. The map revealed that much of Scotland's peatlands are experiencing subsidence, a process by which the land caves in, releasing stored carbon. By better understanding this process, the Scottish government can improve its assessment of the peatlands in order to restore them and prevent future carbon release.

> "For example, this map could be used to more safely implement practices that affect land motion, such as oil and gas production."

This map showcases some of the best features of the scientific process. It distills a plethora of data that is used to better understand the land in Scotland and improve the lives of the people living there. By combining intricate pieces of data into a single map, researchers have provided a tool for Scotland that other countries could use as a model to improve their risk assessment practices to best benefit their country.

In Between Reverence and Reality

A review of *Brief Eulogies for Lost Animals: An Extinction Reader*

BY CICELY KREBILL, BIOLOGY, 2019

DESIGN BY YECHAN YANG, PSYCHOLOGY AND CHEMISTRY, 2022

From the Ainsworth Salamander of North America to the Dodo of the Indian Ocean, Part Time Lecturer in the Departments of Math and Physics, Daniel Hudon, takes the reader on a vast geographic tour, evoking a worldwide mix between a celebration of life and a funeral procession in his newest book, *Brief Eulogies for Lost Animals*. Published in 2017, Hudon's book is broken into regional chapters, each containing eulogies for creatures no longer present on this Earth. Simply enough, Hudon's writing career started out as a New Year's resolution to keep a daily journal. He now has a few books to his name, and in his most recent addition, Hudon takes on an important social message. "I was inspired to write this book because I felt that people really only know about the passenger pigeon and the dodo and not the 900 other species that have become extinct since around the time of the dodo. And because the present extinction rate is much higher than the background rate, I wanted to raise awareness about this biodiversity crisis, because it's human caused and avoidable" Hudon says of his work.

GRAPHIC BY KAREN ARNOLD

> "I felt that people really only know about the passenger pigeon and the dodo and not the 900 other species that have become extinct since around the time of the dodo."
>
> - *Daniel Hudon*

The Northeastern professor's newest work includes mammals and birds, but he also chose to highlight creatures that he knew his readers wouldn't initially relate to easily. He strives to include members from "all across the tree of life," because he believes "they all had a right to be here." Due to this aspect, the reader is sure to both learn the names of, and feel a slight nostalgia for the animals they have never before heard of, let alone shared this planet with. Its pages reminisce on the existence of a wide variety of creatures, including seldom-heard names of bugs such as the Perrin's Cave Beetle. In this insect's eulogy, the reader follows its tale as it is pulled from a well by a pharmacist in the French village of Beausset. Hudon leads the reader to admire the beetle by detailing its swimming abilities and body type. It is just as quickly as you meet this creature, however, that it is taken away from you as its imminent death is described. It is in this style that the reader is repeatedly confronted with the rapid disappearance of life throughout the book.

The structure of these eulogies sets the stage for the reader as Hudon ties the concept of extinction to the grieving process of memorialization; of which, Hudon says "memorializing our loved ones who have passed is a way that we grieve and I felt that concept was pertinent here." Though a somewhat melancholy read, the eulogies are poetic, containing details reminiscent of magic realism. Its descriptions so clear, that in no stretch of the imagination the reader is able to envision the animal in its natural habitat.

Often having only bare descriptions of biology to work with, Hudon describes his process as looking "for any tidbits where I might be able to tell a story about the animal." Throughout the passages, he interweaves quotes from proverbs and outside sources to help illustrate their life and frame the context in which they lived. Ranging from one sentence, to a few pages, Hudon truly demonstrates a mastery of the range of what is considered 'brief', with even the shortest descriptor providing powerful imagery. Its brevity also serves as a clear message to the reader, as it begs the question, which other lives will be cut too short?

Brief Eulogies ultimately takes an unusual angle on conservation, looking specifically at the individuality of each animal that is lost, as opposed to placing them in a greater ecological context. However, it is in this way the book makes its impact, allowing the reader to come to their own conclusions of the effect of this loss of diversity. Hudon's work truly honors the creatures represented in its pages, inspiring the inner conservationist in everyone. To the reader who is seeking a new perspective on an old discussion, *Brief Eulogies* will provide you with an intriguing read, but with its confrontation of our dismal reality, it is not an easy one.

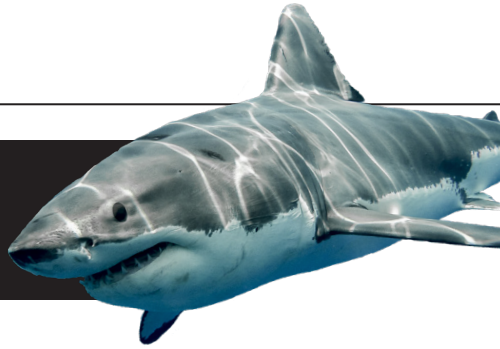
Nature by DESIGN

ARTICLE AND DESIGN BY LILLIE HOFFART,
ENVIRONMENTAL SCIENCE, 2021

Japan's high-speed bullet train's design is not the genius idea of an engineer but rather based on an orange and blue bird. The beak of the kingfisher is the key to both the bird's aquatic diving and the train's efficiency and low noise pollution. Its long, pointed beak allows the kingfisher to dive subtly into the water, and a long pointed nose on the train minimizes the pressure wave it encounters upon entering tunnels.

Taking inspiration from nature is not an entirely new concept — Leonardo da Vinci observed birds and copied their anatomy in designs of his flying machine — but biomimicry, or the design and creation of materials based on nature, was not a popular method of design until relatively recently. According to the BBC, the word biomimicry was first coined in 1998 by Janine Benyus, in her book *Biomimicry: Innovation Inspired by Nature*. "It is important to look at nature - after all, it has had 3.8 billion years to come up with ideas," Benyus said.

Nature has found ways to optimize, and people are beginning to take note. Researchers and entrepreneurs alike have found ways to make man-made designs better; from faster boats to safer push pins to quieter fans.



Selachimorpha
Shark

In 1984, the US rowing team placed second in the Los Angeles Olympics, the first US medal in that sport in many years. Later, in 1987, the Stars and Stripes racing yacht crossed the finish line at Fremantle, Australia, to win the America's Cup. Both vessels were covered in a riblet coating, a technology based on the structure of shark skin.

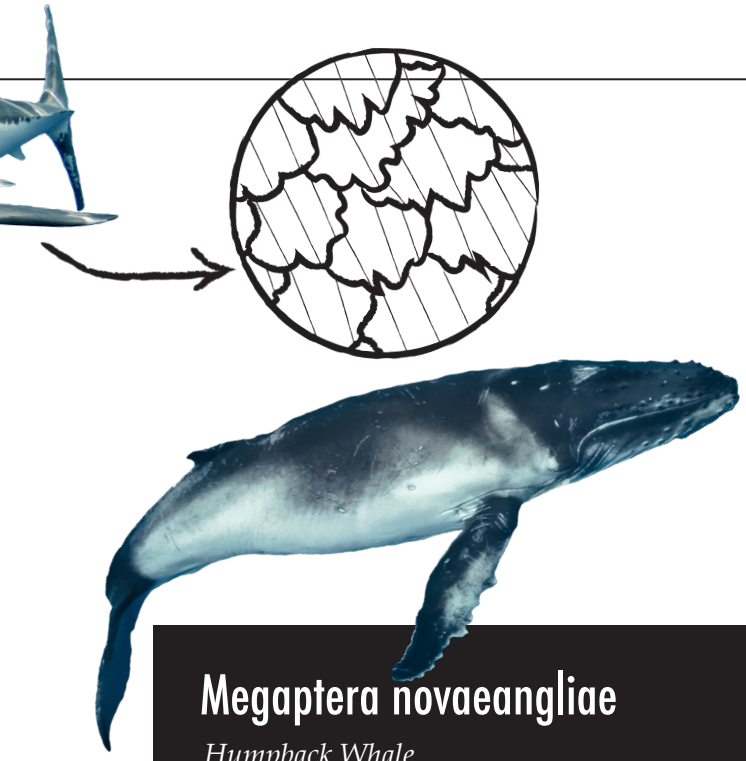
Researchers at NASA took notice of the shark's skin, which is known to reduce skin drag and biofouling, or the growth of organisms like barnacles and algae. The riblets are slightly bent in the direction of flow but "have a pronounced effect on air turbulence," according to NASA's Langley Research Center. The prototypes of the riblets were made into a plastic film with adhesive backing and installed on boats such as the Olympic rowing team's and the Stars and Stripes.

Langley is also implementing the riblet technology into aircraft. According to their website, NASA has a long-term goal of "doubling riblets' drag reduction capability to 15-16 percent, [which] would translate into a five percent reduction in fuel costs." This biomimetic technology has changed engineering both in the air and underwater.

Onymacris unguicularis
Darkling Beetle

Water — it's essential to life, and to desert creatures, it is all too precious. The Darkling beetles, native to the Namib Desert, have come up with a variety of methods for collecting this resource. Some build sand trenches to store water, but Onymacris unguicularis uses its body as a collection system. Microscopic grooves on the beetle's back condense water from the air and channel the drops toward its mouth. Studies on the Darkling beetles show that the population of *O. unguicularis* increases during the dry season.

Akin to the beetle, the Dew Bank Bottle collects water from the morning fog. Left out overnight, the stainless steel dome cools. Dewdrops begin to gather on the surface of the dew bank — corrugated for the maximum surface area — and they slide into the collection space near the bottom. This collection tactic is estimated to produce one glass of water each morning.



Megaptera novaeangliae

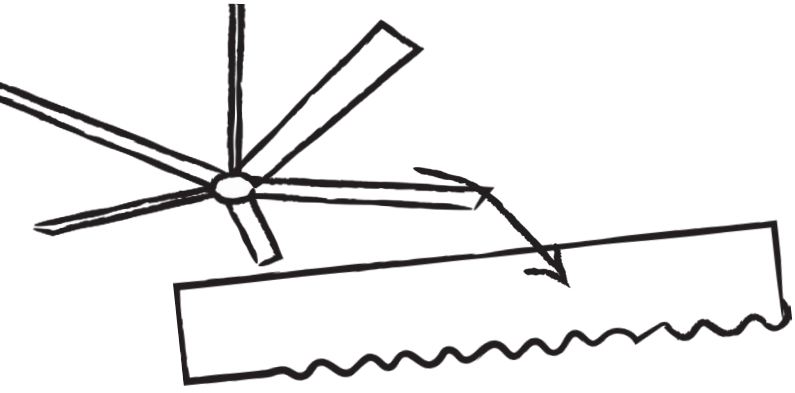
Humpback Whale

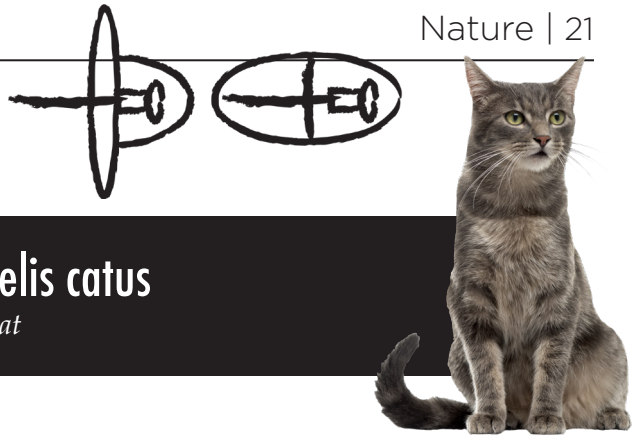
Though it weighs 66,000 pounds, the humpback whale is still able to bank and turn gracefully in the water. The source of their maneuverability: mobile front flippers with rounded bumps, known as tubercles, on the leading edge.

But wouldn't these bumps make the whale less aerodynamic? That's what Professor Frank E. Fish thought when he saw a whale sculpture in a gift shop. Fish is the director of Liquid Life Lab at West Chester University, specializing in fluid mechanics, and began his research on tubercles. Further investigation proved that the sculpture was correct, which disproved the widely accepted notion that leading edges of turbines and airfoils needed to be smooth.

To assess the effectiveness of tubercles, he constructed an unmodified airfoil and one with tubercles on its leading edge. Testing these in a wind tunnel found that the stall angle, or point at which angle of attack causes lift to decrease, was much higher for the tubercle airfoil. This means that whales are able to turn more steeply because of the bumps on their flippers.

Fish now leads a corporation, Whalepower, which is implementing tubercle technology into industrial and agricultural fans and rotors.





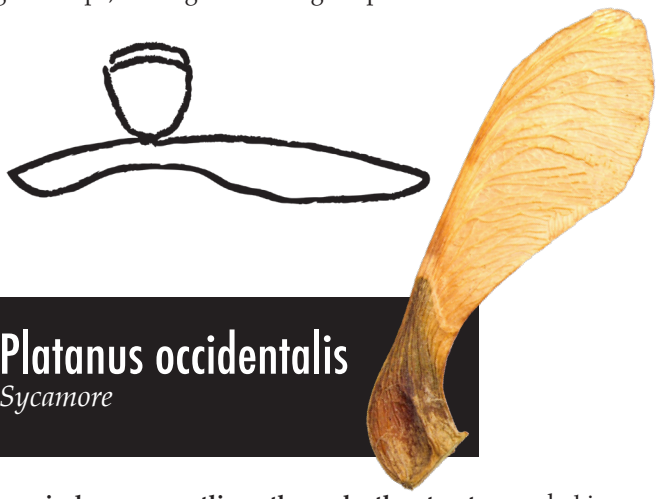
Felis catus

Cat

Placing a thumbtack on the teacher's chair: it's a classic prank. Even when one's grade school years are over, the fear of stepping or sitting on a mislaid tack still lingers. Setting out to create a safer thumbtack, Toshi Fukaya looked to cats for inspiration.

To extend its claws, a cat will flex the muscles and tendons in its paws. When relaxed, a cat will loosen them and the claws will withdraw into the paw. This protects the claws from wear and tear, keeping them sharp.

Just as a cat can retract and expose its claws, Fukaya's design features a bubble of ductile silicone which covers the tack's sharp end. When pushed into a wall, the bubble is compressed and only then exposes the pin. When it is removed, the silicone regains its original shape, once again covering the point of the thumbtack.



Platanus occidentalis

Sycamore

The wind goes rustling through the treetops, shaking branches and initiating a cascade of golden leaves and seeds from the Sycamore tree. As the leaves drift slowly down, the seeds begin their unique helicoptering descent.

The reason the Sycamore seed spins is due to the slightly curved wing on the seed. When falling, the speeds created at the tip of the wing are higher than those near the heavier, rounder seed, and this results in a spinning motion. The balance between the faster spinning outside and the slower moving inside edges of the seed create centrifugal motion and result in a greater stability.

Sycamore Technology is an Australian ceiling fan company founded in 2002 based around the design and engineering of their Sycamore Ceiling Fan. The single-blade unit was tested and modified to produce an optimized airflow. Now the model can operate at half the speed of a conventional three or four blade fan while producing lower turbulence and noise.

Shaking Your Tail Feathers

Courtship dances of birds

BY DANIELLE DOUGLAS, BIOLOGY, 2021

DESIGN BY JULIE MURMANN, BEHAVIORAL NEUROSCIENCE, 2021

In nature, in order to win attention, animals often have to clear the dance floor. For many animals, from the peacock spider to the seahorse, it seems as though dancing is a good way to catch a female's attention. This stunning display is particularly common among birds. These dances are a way for males to show off their abilities and prove that they would be a good mate. Mistakes made in their respective rituals can hint to inexperience and weakness.

In these dances, there are many factors involved, including appearance and sound. This is true for the blue-footed booby, whose dances emphasize their most striking feature: their feet. This is because a bright blue color is due to carotenoid pigments from their diet. Bright feet indicate good health and a compatible mate.

Bright and grand plumage often catches the eyes of females and this can be seen in birds like the peacock. The male birds of this species are the peacocks, while the females are known as peahen and collectively they are peafowl. In mating, they turn their backs to the females, shake their tail feathers, and then turn around revealing a magnificent fan of feathers, which can sometimes constitute as much as 60 percent of their entire body length.

It looks amazing to humans but it most likely cannot compare to what female peahens see, because birds have a much more brilliant, vivid, and refined view of color. Not only do birds have more types of cones (a photoreceptor in the eye) than us, they also have more cones in general. In fact, most birds are known to have some degree of UV vision, which is useful in finding both food and partners.

For peafowl, color, size, and shape matter. Peacocks have a dance called a lek, in which they shake their feathers and sing while females walk around and choose their mate.

Peacocks are not the only birds that use bright plumage to attract a mate. The red-capped manakin has a vibrant red head that contrasts its black body in a manner that draws attention. There are 50 different species of manakins, and these birds practically moonwalk to find a partner. First, they find a branch, to perform their ritual, also a lek. While dancing they make noises in order to get the female's attention and signal to other males to stay away. Female red-capped manakins seem dull compared to their male counterparts with coloring equating to a dull olive-green color with a slightly brownish underbelly. Males, on the other hand, are much more striking with a stark contrast between their jet-black body, crimson head, and neon yellow legs.

> "Mistakes made in their respective rituals can hint to inexperience and weakness."

This color trend among sexes is common for birds as the male is usually the one seeking female attention. However, bright coloring has additional purposes. For example, males use it to win competitions, mark territory clearly, and as referred to with the blue-footed boobies, show off their good health. While it seems males act alone, there are some instances where there is more than one partner.

Many males and their female companions perform beautiful and breathtaking duets, which the grebe species is famously known for. They start their dance by alternating and echoing the motions of their partner. Next, they begin rushing, where they run together on the water. If they can't keep up the stride, couples get cut out. If they are successful, they move onto the next step, a lesser known dance called the "weed ceremony."

The albatross birds also perform non-solo dances with sometimes even having groups consisting of four members as they look for their perfect partner. They will return to the breeding ground for years looking for that perfect partner. Each species of albatross has their own respective and distinctive jig.

Whether it's moonwalking, showing off your feet, or literally walking on water, birds have spectacular courtship dances. For a bird choosing, their mate this needs to be the case. For birds, it is not simply a dance, but their hope for passing on their genes. Maybe we should look up to the birds and wait for that perfect moonwalk to settle.

DID CURIOSITY REALLY KILL THE CAT?

The ups and downs of feline high-rise syndrome

BY KAELEN ENCARNACION, BIOLOGY AND ENGLISH, 2021
DESIGN BY JAMES GOULART, CHEMISTRY, 2021

Have you ever wondered how cats always seem to land on their feet? Believe it or not, there's a term called "feline pesematology" which refers to the science of falling cats, a phenomenon that has generated enough scientific interest to spark a fair amount of research.

One particularly famous study in this field took place during the summer of 1988, in which two veterinarians from the Midtown Veterinary Hospital in New York, Wayne Whitney and Cheryl Mehlhaff, noticed a strange trend occurring in the high-rises of Manhattan. During this time, there were several incidents involving cats falling from windows, ledges, and roofs. It became so prevalent that within a five-month period, 132 cats were taken to the vet due to fall-related injuries.

> "The science of falling cats and the mystery of their nine lives may simply come down to cat-like reflexes and basic physics."

Strangely enough, despite the high rate of cats falling out of the city's high-rises, 90 percent of those brought to the hospital survived. Typically, cats that fell from a height of five stories or below were left with only a few minor bruises. Meanwhile, the cats that fell between five and nine stories sustained serious and life-threatening injuries. This group also exhibited a greater number of injuries per cat. Therefore, one would expect that the greater the height, the more destructive the fall.

The data, however, took an unexpected turn. Of the 22 cats that fell from nine stories or higher, only one cat was fatally injured. One cat fell 32 stories and suffered only minor thoracic trauma and a chipped tooth. So, how is this even possible? To solve this mystery, Whitney and Mehlhaff sought help from a physicist. In their published findings in the Journal of the American Veterinary Medical Association (JAVMA), they used the term "feline high-rise syndrome," originally coined in 1976 by Dr. Gordon Robinson.

Their work concluded the following: the cat floats to the ground, feet first. Imagine a cat beginning to fall from 32 stories high, for example. As soon as it begins free-falling, it will instinctively and immediately position itself upright in midair, with its legs facing downwards. As it falls for 32 floors, it will continue to accelerate until it hits a speed of about 60 mph, after five to nine floors. At this point, the cat will have reached a point where the wind resistance pushing the cat upwards has reached an equilibrium with the force of gravity pulling the cat downwards.

Whitney and Mehlhaff went on to suggest that the cat can sense it is no longer accelerating, but rather has reached its terminal velocity. As a result, its body will naturally relax and orient itself into a "flying squirrel" position with its limbs outward, minimizing the force of impact as the cat slows down enough to hit the ground basically unharmed. Thus, the cat spares one of its nine lives for another day.

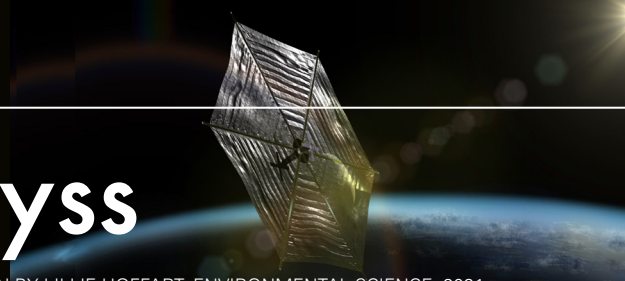
Unfortunately, this means that the cats falling between five and nine floors would not have enough time to reach their terminal velocity and would still be accelerating as they hit the ground – which may explain their many injuries.

However, in a 2010 Radiolab podcast that discussed feline high-rise syndrome, astrophysicist Neil deGrasse Tyson gave his take on the famous study, stating that the data set in their paper is highly biased. "You don't take a dead cat to the vet," he laughed, "I mean you might, but why?"

The study only took into account the cats seen by the veterinarians; excluding all cats that either died from the fall regardless of height or did not require medical attention at all. So, the authors' conclusions may only be supported by a portion of evidence, not all of the cases. Therefore, there are some limitations in the study's scientific accuracy. In fact, Tyson actually went on to challenge Whitney and Mehlhaff's explanation arguing that cats may not actually be able to sense whether they've reached terminal velocity or not, and therefore their bodies wouldn't be able to relax based on this alone, contradicting the original hypothesis.

Nevertheless, while it is not fully understood or agreed upon, the science of falling cats and the mystery of their nine lives may simply come down to cat-like reflexes and basic physics. So, the next time you're worried about a cat stuck in a tree, worry not, wind resistance may just save the day.

Sailing into the Abyss



BY JENNIFER GARLAND, APPLIED PHYSICS, 2021

DESIGN BY LILLIE HOFFART, ENVIRONMENTAL SCIENCE, 2021

The history of spaceflight has depended on chemical rocket engines as the primary form of propulsion. However, fuel limits our exploration range and takes up 95 percent of the weight of the aircraft. New technology in the form of lightweight "solar sails," or photoelectric material utilizing the sun's energy, may revolutionize our access to space, perhaps bringing humans past the moon for the first time.

Indicated by their name, solar sails use the sun's power to move. The sails are made of a thin, reflective material, and photons from the sun collide with the surface, transferring enough momentum to propel. The concept is similar to throwing balls, but photons do not have mass, so the process is not driven by direct impact. Light acts as a particle and a wave, and the energy of the waves is absorbed by the reflective surface of the sails, creating the necessary force in a process called "radiation pressure." According to Newton's Second Law of Motion, F=ma, high acceleration in space travel requires a small mass if there is a constant force from the sun.

Solar sails are much more maneuverable than traditional rockets, because the steering sail equipped spacecraft draws on similar methods used to sail on water. Asymmetric thrust is key, with one side of the sail darkened by an electro-optic coating to turn the body. Though conventional rockets have a higher initial velocity, loss of fuel supplies cause a sharp taper, causing a limit at the solar escape velocity around 36,500 miles per hour. Solar sails allow spacecraft the potential to steadily travel over 60,000 miles per hour, providing a promising shot at swift and efficient interstellar space travel.

The idea of solar sails has been around since 1924 in Russia, and NASA started investigating in the 1990s. Advances in smaller, lighter electronics in recent years have increased feasibility of solar sails.

Now in 2018, NASA is launching the first space probe powered by sunlight and traveling past the orbit of Earth on a mission to reach asteroid 1991 VG. Named the Near-Earth Asteroid Scout (NEA Scout), the small probe will reach space with the International Space Station and be initially propelled by cold gas. Weighing up to 14 kilograms and similar in size to a shoebox, NEA Scout will be energy and cost efficient as it travels approximately two years to gather pictures and data about the asteroid's motion and chemical composition. The observations will provide integral information for planning the first steps for crewed asteroid missions.

Birds of a Feather Flock Together

BY HEATHER OFFERMANN, BEHAVIORAL NEUROSCIENCE, 2019

Regardless of whether you consider them familiar friends or inconvenient enemies, the large, black-necked geese waddling around the Fens are icons for Back Bay residents here in Boston. It wouldn't be a walk to Target without having to play hopscotch with geese droppings, or being cut off in your tracks by a group of these subtly intimidating birds. Commonly named the Canada goose, this species of bird originates in Northern America, breeding throughout parts of Alaska, and even in areas of Greenland.

Although each flock of geese sticks to their own strict migration patterns, many reside in the northern states during the hot summers, and travel down to southern states to keep warm during the frigid New England winters. As for the geese here in the Fens, you will see them around throughout most of the winter season. Aside from their notorious honking calls, Canada geese are known for flying in a V-formation, which has aerodynamic benefits to help these large birds travel far distances.

According to a number of studies, the most prominent benefit of flying in a V is to save energy. A flock of approximately 25 birds can fly 71 percent farther than if a single bird flew on its own, and this is due to their precise positioning. Geese align themselves to be just behind and to the side of the bird in front of them, which creates impeccable timing for the back bird to catch the drift of the flapping wing of the front bird, known as the "upwash" zone. When geese position themselves to catch this free lift, the V-formation is formed. This sweet spot is hard to quantitatively measure for scientists, but they do know that geese are incredibly keen on their spatial surroundings, and they may be able to sense the wind currents of the bird in front of them within their feathers. This positioning of least resistance also requires synchronization of wing flapping, while following the same exact flight path as the bird in front.

Seeing that birds in the back are mooching off the air of the bird in front, it's easy to imagine the leading bird, flying against no beneficial draft, becomes tired fairly quickly. Scientists have studied other bird species to explore this journey, and found that birds are constantly switching positions, meaning that the bird in front is never there for an extended period of time. A flock of white ibises, a bird slightly smaller than geese, switch with a neighboring bird an average of 57 times during a one-hour flight.

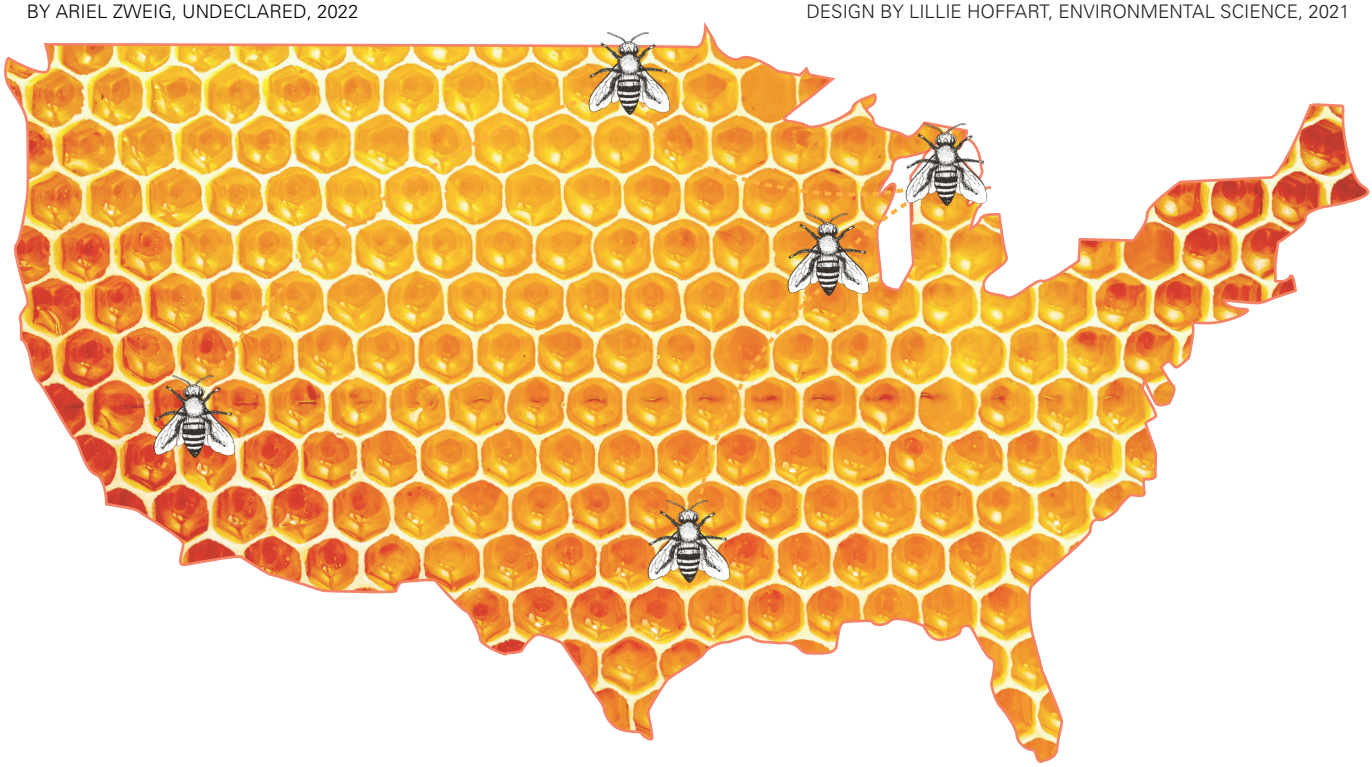
Although local Bostonians may beg to differ, the Canada goose is a creature to be appreciated for their evolutionary, instinctual teamwork skills that turn out to be more than a visual aesthetic in the sky.

Motion Sickness

Transportation and the death of the honeybee

BY ARIEL ZWEIG, UNDECLARED, 2022

DESIGN BY LILLIE HOFFART, ENVIRONMENTAL SCIENCE, 2021



If you have ever been stuck at the airport while your flight was delayed or gotten a leg cramp on an eight-hour bus ride, you know that long-distance travel can be stressful. According to recent studies, excessive travel makes bees feel the same way and may be contributing to their demise.

Every February, over 31 billion European honeybees, known as the *Apis mellifera*, enter California from all over the country. Confined in boxes aboard large trucks, they are ready to sip the sweet nectar of roughly 2.5 trillion almond flowers. They won't stay long. Come summer, it's off to the Dakotas to feast on alfalfa, clover, and sunflowers. Then there's the Michigan blueberries; Wisconsin cranberries; and Texas melons, cucumbers, and, in the fall, pumpkins. Even this lengthy list doesn't cover the extent of the hives' migration as they pollinate commercial crops across the nation.

> "Bees adapted to pollinating local plants and wildflowers in one geographic area, not to being shipped from state to state."

And yet, this constant motion of honeybee colonies may be making them ill in various ways. A study published in 2016 found that bees in migratory colonies had significantly shorter lifespans than bees in stationary colonies. They also had higher levels of oxidative stress. Essentially, there were more harmful free radicals present in their little bodies than they could handle, aging them faster and impeding their ability to resist disease. This could be a result of constantly changing environmental conditions, which especially affects bee development in its early stages.

Even more alarming, when many different colonies are brought to the same region – for instance, California during almond season – disease and parasites are spread rapidly. A 2013 study found that the transport of bees through pollination services led to an increased presence of fungal parasites known as *Nosema ceranae*. When this pathogen attacks, it has been shown to negatively affect the bees' learning, memory, and immune system. It sucks away much-needed nutrients from its host bee and often results in the death of entire colonies.

Bees adapted to pollinating local plants and wildflowers in one geographic area, not to being shipped from state to state. The constant change of environment, many argue, is just not natural for them. Some scientists believe this excessive transport may be one of the many contributing factors to colony collapse disorder. To reduce the harmful effects on migratory beehives, experts have suggested simply providing them better access to food. Others have argued for more far-reaching systemic change, such as restoring native wild bee species to pollinate crops in their own regions rather than transporting the ubiquitous European honeybee.

Earthquakes Make Waves

An investigation into how earthquakes generate tsunamis

BY PAULA HORNSTEIN, BIOLOGY, 2020

DESIGN BY FIONA GRIDLELY, COMPUTER SCIENCE AND DESIGN, 2021

Around midnight on January 23, 2018, a powerful earthquake shook just off the coast of Kodiak, Alaska. The United States Geological Survey (USGS), the agency of the federal government that deals with natural resources and disasters, initially cited the earthquakes at an 8.2-magnitude on the Richter scale, a system that quantifies the strength of an earthquake on a logarithmic scale. Tsunami warnings were issued for the southern coast of Alaska and the western coast of Canada, and tsunami watches were issued for the west coast of the United States through Baja California. The USGS later corrected their statement to a 7.9-magnitude, and the tsunami advisories were canceled within four hours of the initial quake, after many living in the warning zone had evacuated to higher land.

In 2011, an earthquake off the Pacific Coast of Japan reached an 8.9 on the Richter scale, resulting in thirty-foot waves that devastated the country. While there is a significant difference in the magnitudes of these earthquakes, tsunamis can occur at any magnitude above 7.0, according to the USGS. In 2010, a 7.7-magnitude earthquake off the coast of Mentawai, Indonesia resulted in nine-foot waves, displacing 20,000 people.

This begs the question, why do some strong, oceanic earthquakes cause tsunamis, while others do not?

The answer is three-fold.

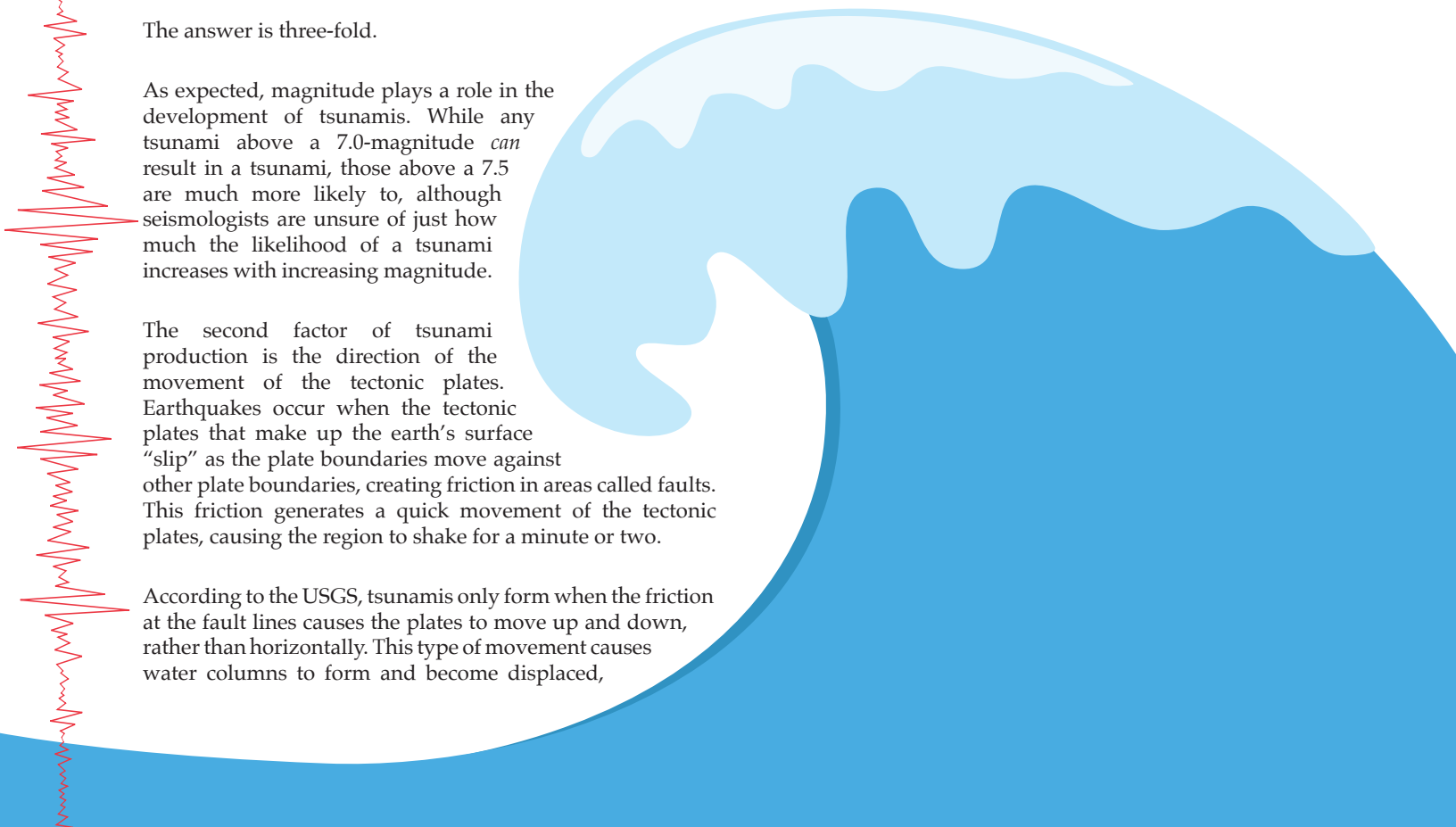
As expected, magnitude plays a role in the development of tsunamis. While any tsunami above a 7.0-magnitude *can* result in a tsunami, those above a 7.5 are much more likely to, although seismologists are unsure of just how much the likelihood of a tsunami increases with increasing magnitude.

The second factor of tsunami production is the direction of the movement of the tectonic plates. Earthquakes occur when the tectonic plates that make up the earth's surface "slip" as the plate boundaries move against other plate boundaries, creating friction in areas called faults. This friction generates a quick movement of the tectonic plates, causing the region to shake for a minute or two.

According to the USGS, tsunamis only form when the friction at the fault lines causes the plates to move up and down, rather than horizontally. This type of movement causes water columns to form and become displaced, creating a wave of energy and propelling water upwards so that the waves become exponentially higher.

The third factor affecting the formation of a tsunami is the topography of the seafloor between the earthquake's epicenter and the nearest land. Seismologists have found that the texture of the sea floor, notably the ground's vertical movement, can amplify or inhibit the energized waves as they approach the shore.

As we have seen since the Great San Francisco Earthquake of 1906, earthquakes themselves have the potential to cause major damage to populations and structures. If an earthquake has a large enough magnitude to cause such destruction, it is likely that a tsunami could form and add to the devastation. As of 2017, there are more than 50,000 evacuees of the 2011 Japan earthquake that are still displaced, as over 1.1 million homes were at least partially destroyed. However, seismologists have made remarkable progress in monitoring the factors that cause earthquakes and tsunamis. As of the present day, seismology has come so far as to be able to detect an approaching tsunami and give those in coastal areas ample warning before it hits. One can hope that the same will soon be said for monitoring earthquakes in the near future.



A Step Toward the Future

Designing robots that can move realistically

BY AMANDA BRETTI, CHEMICAL ENGINEERING, 2019

DESIGN BY SILVIA DIAZ, DESIGN, 2021

It's a familiar scene in science fiction movies: average citizens going about their daily lives, interacting not only with other humans, but also with incredibly realistic humanoid robots. They behave, speak, and walk just like we do. But how would we go about developing such robots? While sci-fi movies tend to focus on the robots' emotions, or lack thereof, one of the biggest challenges that we must overcome is in making robots move similarly to humans.

A group of researchers in Tokyo is attempting to solve this problem. They believe that humanoid robots could give us a better understanding of the human body, allowing us to conduct experiments that would be difficult to perform in human subjects. Humanoid robots have been developed so far, but they still lack the range of movement of actual human beings. The researchers believe that one flaw in the design of humanoid robots is an emphasis on electronics and engineering. Instead, they want to draw from our knowledge of human biology to create what they call a "musculoskeletal robot," named this because its structure imitates the structure of the human musculoskeletal system.

In order to design a musculoskeletal robot, the researchers collected various data about the human body. In particular, they were interested in the lengths and shapes of bones, the arrangement of muscles, and the structure of joints. Once they had collected enough statistical information, they built a skeleton and started fitting muscle actuators and joints into place. The muscle actuators consisted of motors, sensors, and wires: components needed to replicate real muscles. Since they had a limited amount of space, the scientists identified the most important features of the human musculoskeletal system and tried to simplify them.

The team developed two musculoskeletal robots: first, one named Kenshiro, and then an improved version named Kengoro. Both robots' muscle actuators contained sensors that detected information such as measurements of muscle length and temperature. The robots were then programmed to use this information to control their muscles and balance. Kengoro also had fingers and toes to help it interact with the environment like humans do, as well as an artificial perspiration feature in its skeleton to prevent its motors from overheating.

Once they had built the musculoskeletal robots, the researchers compared their body structure and range of movement to that of humans. Kengoro's bone length differed from that of humans by less than one percent. In addition, Kengoro only weighed 16 percent more than the average person. However, Kengoro had deficiencies regarding two of the factors that most affect the ability of musculoskeletal robots to move realistically: the number of joint degrees of freedom (DOFs) and the number of muscles.

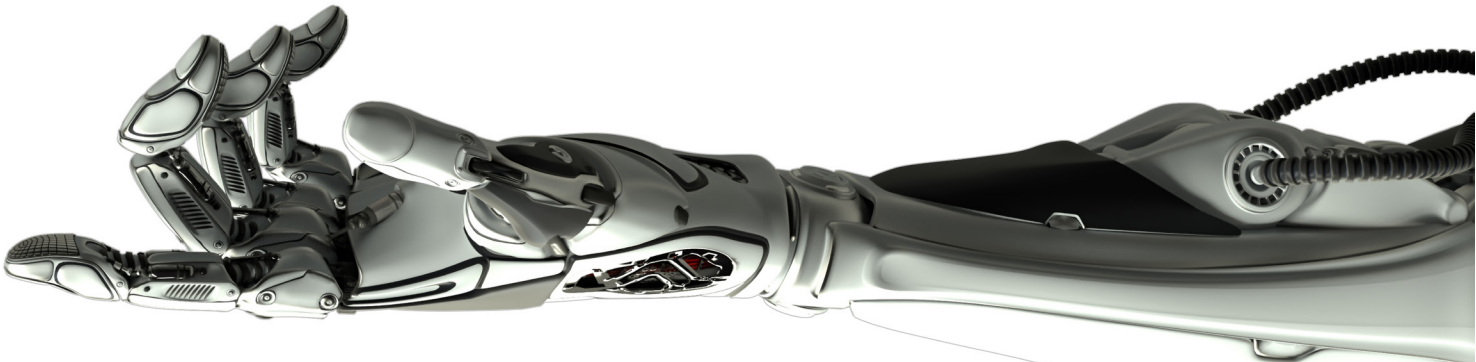
The DOFs of a joint are the number of different ways that it can move. For example, the human shoulder joint has three degrees of freedom; people can move their arms back and forth, raise their arms away from their sides, and rotate their arms inwards or outwards. Whereas humans have 548 joint DOFs, Kengoro only had 174. Similarly, the robot had only 49.1 percent of the muscles of a human.

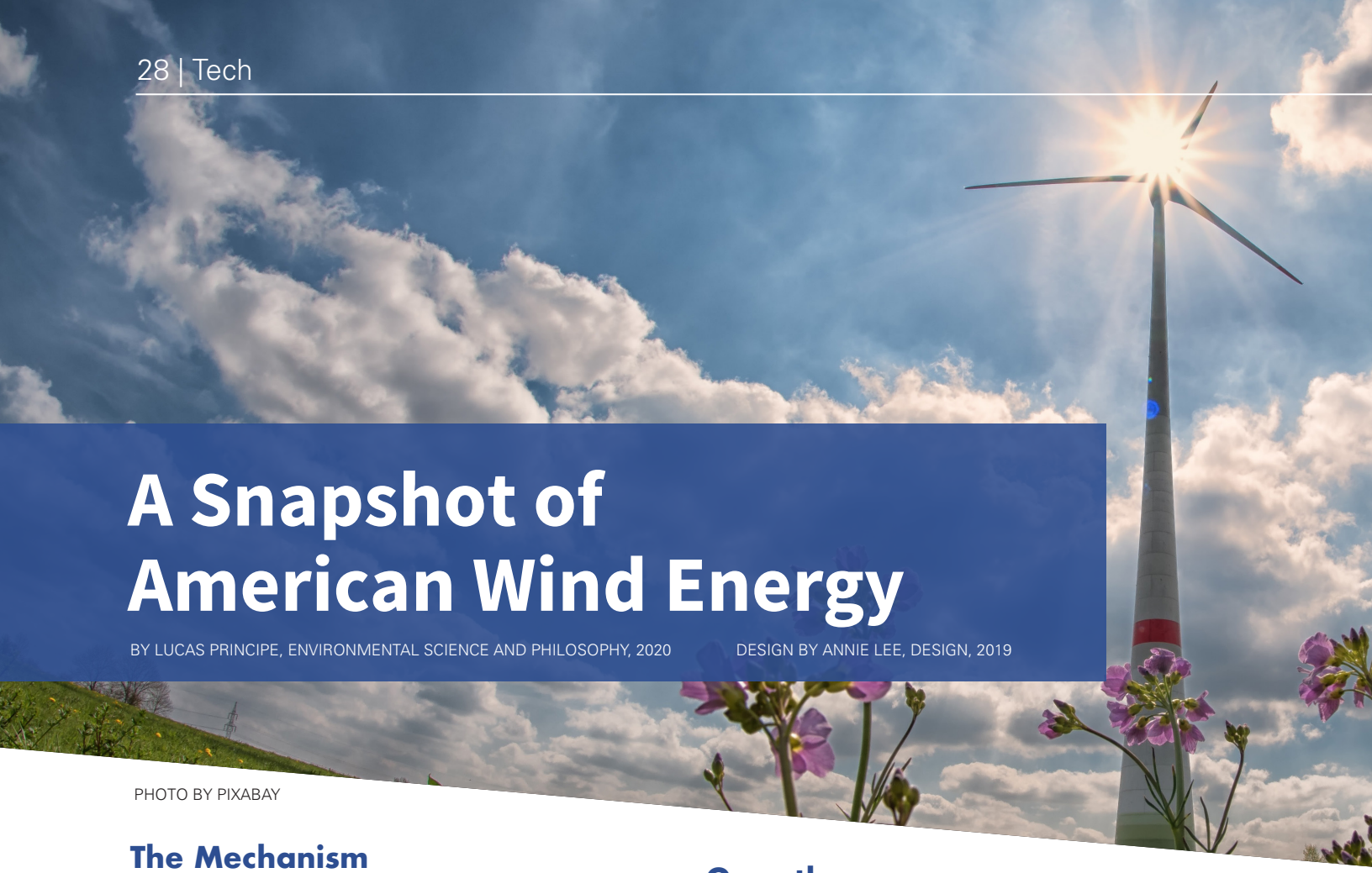
Despite its lower number of joint DOFs and muscles, Kengoro was able to make accurate, flexible poses. The researchers compared the angles of the robot's joints to the angles of human joints in the same poses and found that they were very similar. They attribute Kengoro's realistic movements to the robot's many joints, such as multiple spinal joints, and its similar muscle arrangement to humans.

The musculoskeletal robots designed in this study are a great improvement on previously designed humanoid robots. Kengoro has the most joint DOFs and muscles of any life-sized humanoid robot. While further research is needed, especially to increase the number of joint DOFs and muscles in the robots' hands and feet, the robots are an impressive feat of engineering that could have many uses in the future.

One possible application of the robots is for collecting data about the human body, such as measuring certain muscle parameters during different movements. The robots could also be used as car crash dummies, as their ability to move realistically could tell us more about the way humans respond during car accidents. Interestingly, a team of scientists at the University of Oxford believes that musculoskeletal robots could aid tissue engineering, acting as moving scaffolds with the mechanical stimulation needed to grow musculoskeletal tissue. Overall, these robots provide numerous possibilities for the future, even if we're still a long way off from the visions of sci-fi movies.

Science Robotics (2017). DOI: 10.1126/scirobotics.aaq0899
Science Robotics (2017). DOI: 10.1126/scirobotics.aam5666.





A Snapshot of American Wind Energy

BY LUCAS PRINCIPE, ENVIRONMENTAL SCIENCE AND PHILOSOPHY, 2020 DESIGN BY ANNIE LEE, DESIGN, 2019

PHOTO BY PIXABAY

The Mechanism

Wind power, which is generated from wind turbines, harnesses the energy of wind currents to create electricity. The currents push on the slanted blades of the wind turbine and flow off one side to rotate them the opposite way. These turbines are connected to a rotor that rotates in a generator to create electricity.

Understanding Energy

Wind energy is typically measured in Megawatts (MW). A watt is the standard unit of power and represents the rate at which electricity is being used at any given moment. One megawatt, or 1,000,000 watts, is roughly equivalent to the power produced by 10 standard automobile engines. The average 1.5 MW wind turbine will produce enough electricity to power around 332 American households for a year.

Why Wind?

Those elegant air currents that speed over our heads each day are a pollution-free, renewable, and highly abundant source of energy. As long as the wind keeps blowing, turbines can continue to gather electricity for us. Plus, wind turbines are incredibly space efficient, and prices for wind energy have decreased significantly over the past 40 years.

Current Capacity

As of the most recent measurement in October of 2017, there is now around 85,000 MW of installed wind capacity in the United States. This breaks down to more than 52,000 wind turbines spinning gleefully in 41 states, Puerto Rico, and Guam.

Growth

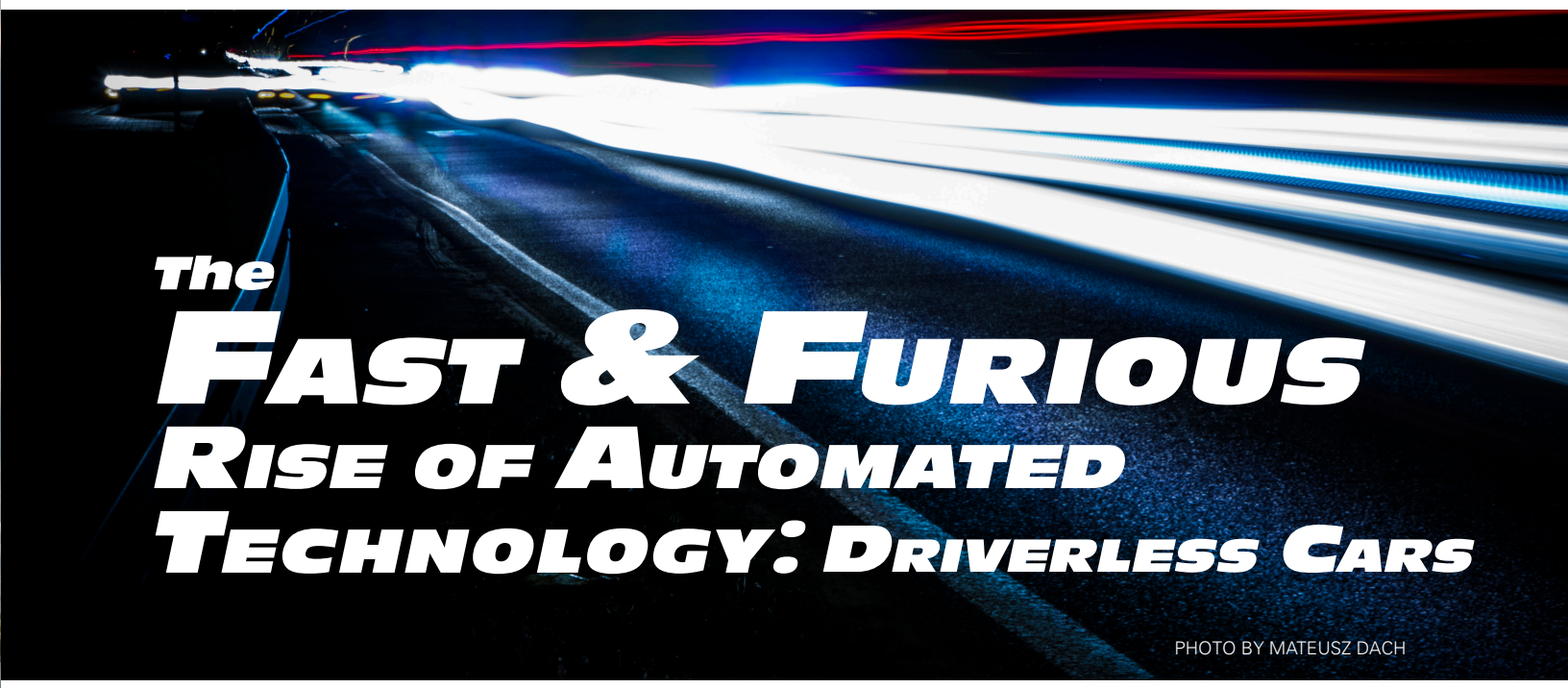
Currently, there is around 14,000 MW of wind power infrastructure in construction and 16,000 MW more in development for next year. This represents a 27 percent increase from 2016. Additionally, in 2010 wind energy accounted for 2.3 percent of the nation's electricity generated while in 2016 it accounted for nearly 6 percent: more than doubling its portfolio in only six years.

The All-Stars

Running away with this category is Texas with 21,000 MW installed. Next is Iowa (7,000 MW), Oklahoma (6,600 MW), California (5,600 MW), and Kansas (5,110 MW). Massachusetts, our lovely home, does better than some states in the northeast with 115 MW installed. Yet it still drags behind the likes of New York and Pennsylvania, each with over 1,000 MW installed.

Needs Improvement

Sadly, much of the southeast United states has virtually no utility-scale wind capacity or wind infrastructure installed. This is due to two reasons. The first is low average wind speeds in these regions. More importantly, however, it is due to a lack of Renewable Portfolio Standards, the percentage of energy that is required to be generated from renewables, from state governments who don't feel a need to invest in wind power. This is despite the fact that the Department of Energy has repeatedly stated that wind can be a viable source of renewable electricity in all 50 states.



The Fast & Furious Rise of Automated Technology: Driverless Cars

PHOTO BY MATEUSZ DACH

BY YAEL LISSACK, BIOENGINEERING, 2021

DESIGN BY ANNIE LEE, DESIGN, 2019

Imagine you and three friends are cruising down the street in a driverless car. The car turns a sharp corner when suddenly it sees a group of four children playing hopscotch in the middle of the road. The car has two options: either continue on its path, tragically hitting the group of children, or swerve into the divider, killing you and your three best friends. What should the car do?

This dilemma introduces the complex discussion surrounding the morality of autonomous vehicles (AV), prompting the question, "How is a non-living machine supposed to make life-or-death decisions?" As autonomous cars make their way from futuristic sci-fi movies to places like the Seaport, the ethical considerations of machine intelligence are becoming significantly more relevant.

> "As autonomous cars make their way from futuristic sci-fi movies to places like the Seaport, the ethical considerations of machine intelligence are becoming significantly more relevant."

The initiative to increase the number of self-driving cars stems largely from the fact that around 90 percent of all motor vehicle accidents are caused by human error. A car that reduces accident rates while simultaneously allowing a user to finish up on work emails seems to be worth the investment. There are, however, bumps on the road that need to be tackled before they can get anywhere. Companies like Google, Hyundai, and Volkswagen have already invested largely into this technology. Most notable is Google's program, Waymo. This program boasts a product that will improve road safety and mobility, with three and a half million miles already under the cars' belts. Google claims that their cars can "[predict] the future behavior of other road users" and are "able to respond quickly and safely to any changes on the road," but offers no insight to how the cars make decisions such as in the previous scenario.

Programming these kinds of decisions into autonomous vehicles is no easy feat. If a series of very unfortunate events leads an AV to decide between hitting an old man and a young woman, who does it choose? To further explore the ethical dilemma presented by these hypothetical circumstances, several researchers at MIT created a program called Moral Machine. The website asks participants to make life-or-death decisions in numerous theoretical situations, and gathers these statistics for further consideration. Large disagreements about individual scenarios further demonstrate that these decisions are not at all easy.

While companies like Tesla and Google have not sat down and worked through every hypothetical scenario an AV could face, cities around the world like Boston are already embracing this emerging technology. Though driverless cars may seem like a luxury of the future, machines are learning how to mimic human behavior at a rapid pace. Perhaps in five or ten years, cars with drivers will be almost as taboo as they are now without.

To contribute to the Moral Machine, users can visit moralmachine.mit.edu.

A Most Mysterious Matter

BY KEVIN PARLATO, MECHANICAL ENGINEERING AND PHYSICS, 2021

DESIGN BY KRISTI BUI, COMPUTER SCIENCE, 2021

It's called dark matter. It makes up almost one-third of the entire universe, but nobody knows what it is. It might just be one of the most important discoveries of the century and it was found by studying motion.

For the past century, modern technology has allowed astrophysicists to study the motion of galaxies. One such device, a spectrograph, allows scientists to measure the wavelength of light produced by stars inside galaxies. The stars emit well-defined wavelengths, but the detected values are shifted up or down based on the stars' motion relative to the observer. Scientists graph this information onto Galaxy Rotation Curves (GRC) that display the orbital velocities of different stars with respect to their radial distance from the center of the galaxy. This is where things get spooky.

> "There is not enough mass present in the galaxy to create enough gravity to hold together the high-velocity orbits of stars."

For all celestial systems with mass concentrated in the center, the GRC should obey a specific relationship called Keplerian Decline, meaning that the velocity of the objects orbiting it should decrease with the square root of their distance from the center of the galaxy. For example, solar systems exhibit Keplerian Decline because their mass is concentrated in the center and the planets closest to the star have greater velocities than planets farther away. Based on observations, galaxies have similar mass distributions to solar systems, so velocities of stars in the galaxies should behave like solar systems. But they don't. Instead, their GRCs display a constant relationship. The stars near the outer edges and the stars near the center of galaxies have similar velocities.

It was very surprising to find objects with the same velocities regardless of radial distance from the center. This is because there are now two equally correct yet conflicting observations. The observed velocities imply the galaxy has a uniform mass distribution like a solid disk, but the observed radiation implies that the mass is concentrated in the center, like a solar system. If both are correct, then there is not enough mass present in the galaxy to create enough gravity to hold together the high-velocity orbits of stars. They should break away, but this does not happen.

Enter "dark matter," the term given to the idea of unknown particles filling a galaxy with enough mass to create sufficient gravity to keep stars from flying off into space. It could be a new form of matter or it could be a new set of laws to govern motion on the large scales galaxies operate in. If it was a new form of matter, it would be weak in its interactions and therefore extremely good at hiding. So basically, a wimp… or, more specifically, a WIMP.

At particle accelerators like the Large Hadron Collider (LHC) at CERN, physicists hope to detect "Weakly Interacting Massive Particles," or WIMPS for short. WIMPS are aptly named because they interact very weakly with electromagnetic radiation. This weak interaction would explain why scientists observe less than the required radiation to explain the gravity of galaxies. These particles, which some think could be the elusive "dark matter," have never been detected. They have mass but no electric charge or anything else particles can have that make them interact with other particles.

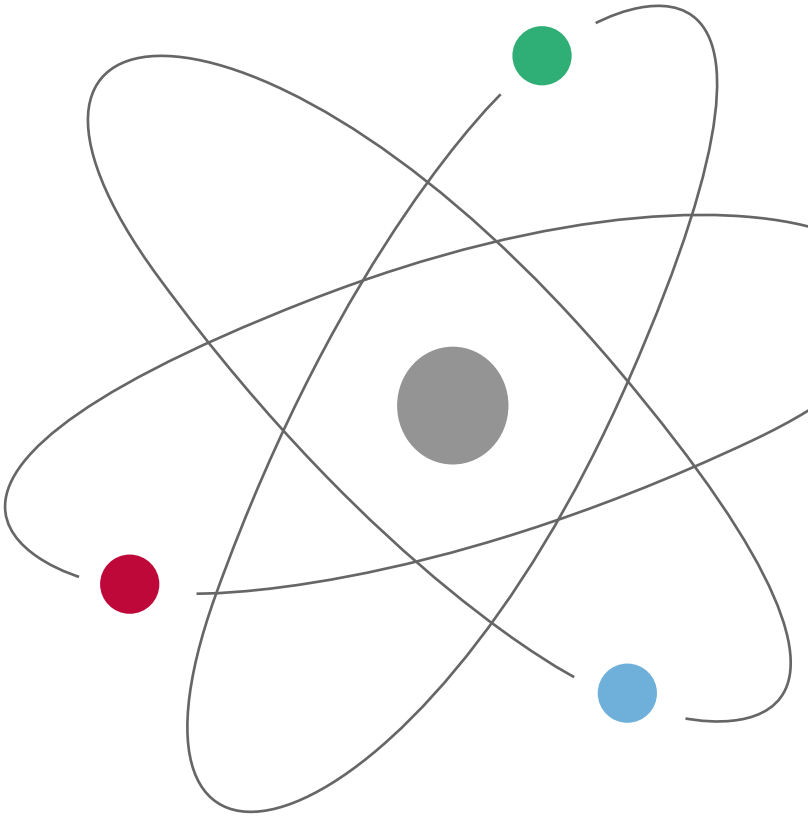
Northeastern University Professor of Physics Emanuela Barberis is one of the experimental physicists at CERN hoping to find evidence for dark matter. According to Barberis, "one of the foci of the LHC during the next rounds of experiments will be to find 'dark matter' candidates." By smashing protons together at high energies, particle physicists convert kinetic energy into rest energy, otherwise known as mass. If the LHC produces a WIMP, its mass will elude the detectors and there will be less energy after the collision then before. This missing energy is the mark of dark matter. Physicists detect missing energy regularly during collisions, but it's hard to tell if it's the infamous dark matter.

As Barberis explained, "we might have produced it, but we haven't singled it out yet. Other things mimic that signature." The physicists at the LHC are working on new improvements to increase their chances of detecting WIMPS. Plans to increase the intensity of collisions will provide more data and hopefully resolve if the LHC is actually producing dark matter. The search is a constant reminder that nature remains a mystery needing to be solved. "We have to go beyond the limits of what we can currently do," she encouraged.

PHOTO BY MAXWELL HAMILTON

Why Goliath Moves David

BY JAMESON O'REILLY, PHYSICS AND MATH, 2019
DESIGN BY KRISTI BUI, COMPUTER SCIENCE, 2021



Typically, the bigger something is, the harder it is to move. Almost everyone understands this intuitively and uses it to do things like choose between a cart and a hand basket at the grocery store. Inertia, as this property is called, helps explain why aircraft carriers and construction equipment must be so huge. Following this logic naively, it may seem strange that mankind's largest, most complex machine is dedicated to moving protons, some of the smallest things in existence.

> "It may seem strange that mankind's largest, most complex machine is dedicated to moving protons, some of the smallest things in existence."

Indeed, the Large Hadron Collider (LHC), a 17-mile ring outside of Geneva, Switzerland, is used to accelerate protons to very near the speed of light so that they can collide with one another and erupt into other fundamental particles. In some sense, the LHC must be big because the proton is so small. A proton is easy to move, but scientists want it to move in very specific ways, so it must be kept in a vacuum, away from anything that could disturb it. Additionally, a proton can't just be pushed like a refrigerator; it has to be accelerated and steered with very precise electric and magnetic fields, respectively. Otherwise, it would get lost. The other reason the LHC must be so large is that as the protons get closer to the speed of light, they become harder to accelerate, effectively becoming more massive. Eventually, huge amounts of energy are needed to further accelerate the particles.

Once fully accelerated, the protons are made to collide at four points along the ring and the collisions are studied in hopes of finding new particles and learning more about the behavior of what is already known. The LHC is the most extreme and well-known example, but particle accelerators are used for many things in the modern world. In proton therapy, particle accelerators are used to hit tumors with high-energy protons that damage their DNA. Cancer cells are less able to repair themselves than normal cells, so they are disproportionately affected. Accelerators can also be used to inject ions into semiconducting materials to dope them and adjust their properties. Even the Louvre has its own particle detector to help it study and date the art and artifacts in its collection.

None of these machines are even close to the size of the LHC, but they are still impressive feats of engineering. Most are linear accelerators, which use oscillating electric fields to alternately push and pull particles along a straight line. Generally, they do not impart as much energy as a circular accelerator because the acceleration stops at the end of the detector, whereas a particle travelling in a circle can keep going indefinitely. Its energy is limited only by special relativity and the radiation it gives off during acceleration.

Follow us: @nuscimag
Read our work: nuscimag.com
Subscribe to our newsletter: bit.ly/nusci
Contact us: nusciencemag@gmail.com

Supported by the
Student Activity Fee