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NU SCI

Heat

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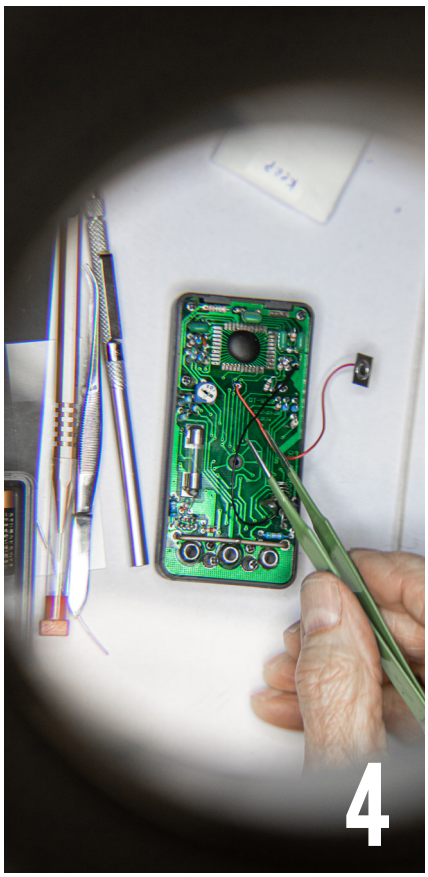


LETTER FROM THE EDITOR

A warm, smoky cabin in the middle of a snow-dusted, pine-needle forest is a welcome thing. So, too, is a whistling fire on a brisk summer night, and the sun against your back as you nap on a rock cooled by the riverside.

A forest fire raging through northern California, however, is not. Neither is touching the stove top before you're old enough to know better, nor biting into a slice of pizza that hasn't yet had time to cool.

Heat represents a delicate scale: in moderation, it is necessary for species and climatic flourishing, but in excess or deficiency is responsible for suffering and inhibition, not to mention a catalyst for so many geological and astronomical processes.

It's also one of the most elemental phenomena. Heat is simply the production of the vibrations and collisions of atoms in motion. It therefore has a profound impact on all things biotic and abiotic in this world.

Heat is quite topical as well. The last five years on Earth have been the hottest mankind has ever recorded, and there's strong evidence to suggest the next five may set a new record. Climate change has been dubbed "the defining issue of our time," by United Nations Secretary General António Guterres. No shortage of human consequences will you be able to find once its full effects hit.

If we narrowed our focus last issue with "Roots," we've since widened our lens to encompass "Heat."

Inside this issue, read about the theory of spontaneous human combustion, the biological result of a skin burn, the chemical basis behind that warm fuzzy feeling of love, and the ecological processes that follow forest fires.

If you're curious how exactly leaves change color when autumn arrives, if you'd like to learn more about how chili peppers could be used to treat lung cancer, or if you've always had an opinion on what is the optimal temperature to keep the office thermostat at, we have a piece for you.

So please, brew a fresh cup of coco, throw a new log in the fireplace, grab your thickest pair of wool socks, and enjoy flipping through our second issue of the Fall 2019 semester: Heat.

Lucas Principe
Editor-in-Chief

STAFF

Cover Design by Lillie Hoffart

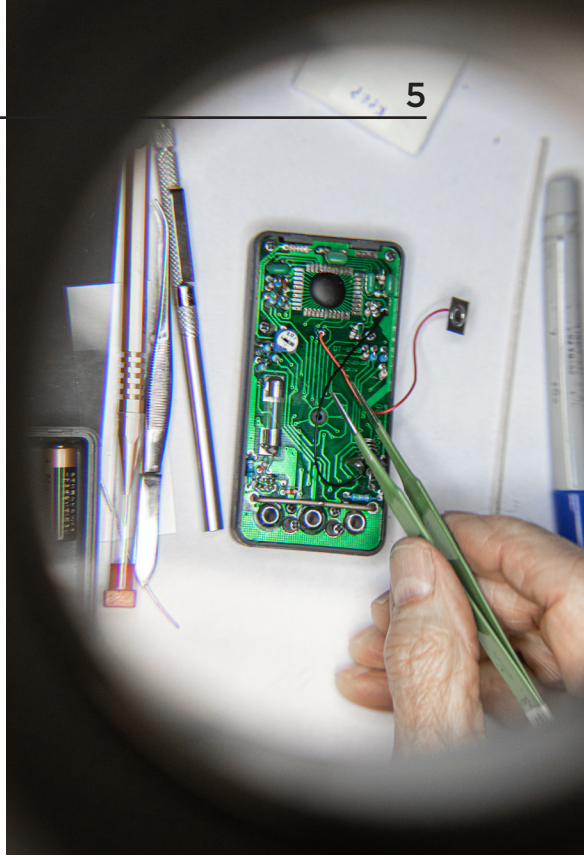
The future of magnetic materials

A conversation with Dr. Don Heiman

BY DATTU KALLURI, BIOCHEMISTRY, 2022

DESIGN BY KYLA VIGDOR, DESIGN, 2021

PHOTOS BY GUS MUELLER, BIOENGINEERING, 2022



The Nanomagnetism Lab here at Northeastern University looks like a filming location for a new sci-fi film—at the entrance, emblazoned are the bright red words "CAUTION: HIGH MAGNETIC FIELD." As you walk in, you see a long metal rod with a tangle of thin wires around it hanging from the door leading to Dr. Don Heiman's office. "This is a cooling unit for a quantum computer," he explained, seemingly delighted to share his research. As an experimental physicist, Heiman specializes in spintronic materials.

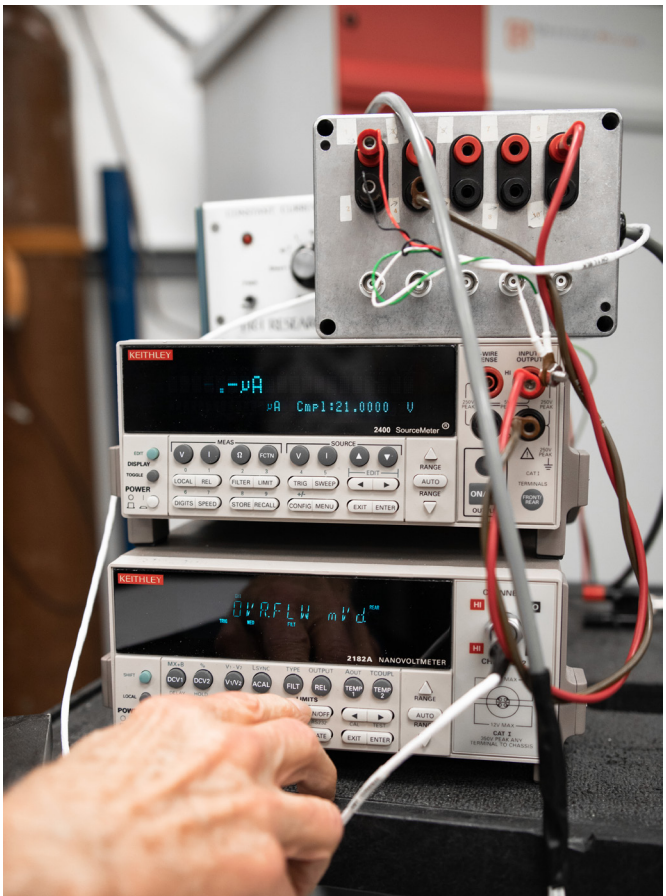
"Of course, spintronics is about a lot more than just computing," he continued, gesturing to the many contraptions strewn across the lab. Spintronics at its core is about taking electricity a step further. Instead of just using electricity to power devices, the properties of the individual electrons themselves are used to transmit data.

"Electrons have a property called intrinsic angular momentum - quantum spin," explained Heiman. This momentum can be either of two opposite values. By polarizing the electrons so that only the ones with specific spin make it through a filter, the electrons can be used to store data or make special materials.

The applications for computing are myriad: storing large amounts of data more efficiently, computing faster, and creating a fail-safe for quantum computers. One of the biggest problems with quantum computers is their propensity for errors in computing. By creating a spintronic device called a topological insulator, which behaves as a conductor on the surface but an insulator in the interior, errors can be reduced.

Though Professor Heiman has an even more pragmatic use: "Polarized currents dissipate less energy." Understanding how to effectively create polarized currents can lead to more efficient devices, leading to lower energy consumption.

> "Instead of just using electricity to power devices, the properties of the individual electrons themselves are used to transmit data."



Doing this, however, has proven tricky. This is why his lab, in conjunction with labs at Massachusetts Institute of Technology, The University of Notre Dame, and the National Security Administration, was recently awarded a $90,000 grant from the National Science Foundation Division of Materials Science.

His lab is specifically focused on developing methods to create these special currents at room temperature. To do this, he is using spin gapless semiconductors and spin filters, which channel electrons into different currents based on their spin. He is also working with other labs to create metals called Heusler compounds, which combine these two properties with magnetism to be applied to quantum information processing.

We get HEATed: The Husky Environmental Action Team

BY HUGH SHIRLEY, BIOCHEMISTRY, 2019

DESIGN BY KYLA VIGDOR, DESIGN, 2021

"**Environmentalism is not political,** it's based in science," said Winifred Gallogly, a 4th year Biology major and president of the Husky Environmental Action Team. HEAT is a club at Northeastern engaged in environmental activism. The team has set their sights on issues of food sustainability, plastic waste, and more. But as a club that's actively attempting to sway Northeastern and its students, HEAT faces significant challenges every step of the way.

The group was founded 35 years ago as the Husky Energy Action Team. The goal back then was to advocate for clean energy and for Northeastern to divest from fossil fuels. As the scope of the club expanded from energy to other environmentally relevant topics, the name change was a logical step.

Over its history, HEAT has served as an incubator for many initiatives. Members team up to work on issues that are personally important. Recent incubators have focused on establishing a community garden, called NU Grounds Garden, or on installing more hand dryers to reduce paper towel waste. While these incubators aren't always successful, several of them have spawned offshoot clubs that focus on developing the incubator's goals independently. DivestNU is one club that has its roots in HEAT and was an active voice of protest against Northeastern's financial ties to the fossil fuel industry. Other sapling clubs from the HEAT tree include Trash2Treasure, Slow Food NU, and an up-and-coming club called the Food Recovery Network that takes restaurant leftovers to a women's shelter.

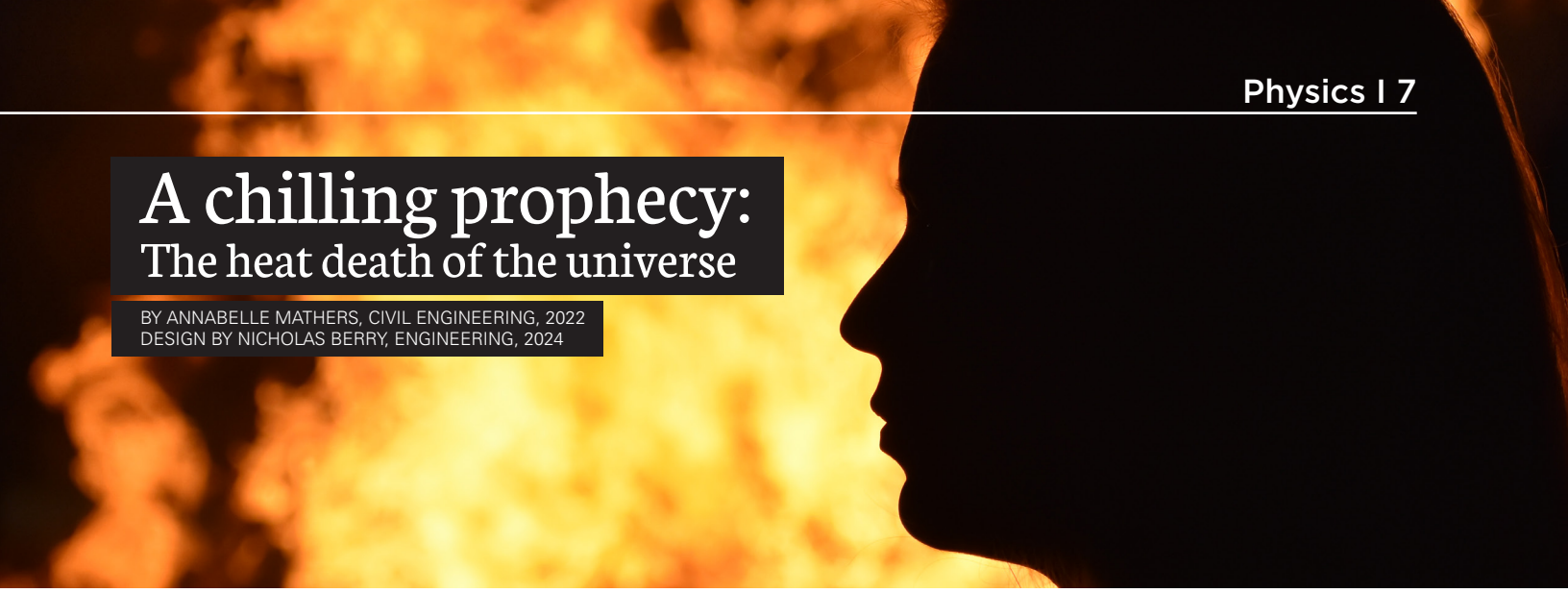
Gallogly joined the club during her first year at Northeastern and was swept up into the activity surrounding President Donald Trump's election, when HEAT participated in several demonstrations. Gallogly has served as president for two years and has directed HEAT's recent goals and strategies to reflect her sustainability mindset. "My philosophy on sustainability and the education that we give to Northeastern students is that [it] should be daily thinking. You should be an activist for the issues that you care about," Gallogly said. "I've done that in my own way and it's not really the same as what my prior presidents had done."

Gallogly demonstrated that mindset by changing HEAT's annual Do it in the Dark event, an energy saving competition for freshman dorms. Historically, they've held a barbeque to get students excited about participating, but only a handful of people would show up. This year Gallogly decided to avoid food and paper waste. HEAT paired the event with the global climate strikes and had students recycle cardboard for sign making. "I thought it was more beneficial and a good teaching moment than having a barbeque that 10 people show up to," Gallogly said. That practice-what-you-preach motto is strong with Gallogly's HEAT. While the shift from big-and-showy towards more lowkey events might not score HEAT much recognition, it does speak volumes about their renewed dedication to environmental action.

The students in HEAT are passionate about their work, but roadblock after roadblock does begin to take its toll. Faculty are often supportive of HEAT's initiatives, but many final decisions are made by administrators who might not share the same goals. Gallogly's incubator attempted to reduce the sale of plastic bottles from campus stores. They were met with administration claims that such a dramatic change would be impossible. Gallogly argued that "by stocking the bottles, you're encouraging people to buy them. If you decreased the number of bottles and told people why and showed that you cared about [that issue], then change would happen." After months of red tape, the project fizzled. To thank Gallogly for her efforts, she was gifted with a reusable metal bottle, on-sale now at the university bookstore.

While HEAT might not often instigate change at the administrative level, the club is a poignant educator for students interested in sustainability. They host talks on a diversity of sustainability issues. Gallogly worries that inundating bright-eyed freshman with the many ways they are contributing to environmental degradation might create apathetic students. "I feel like it can be overwhelming because every week we are like, 'this is a new facet of your life … that you should be changing your mindset about,'" Gallogly said. With Gallogly graduating this Spring, a new era for HEAT could be on the horizon. She is preparing to pass the torch on to younger students, but she wants the next E-board to take HEAT in whichever direction they want. "HEAT is here for everyone, it's environmental issues in general."

PHOTO BY SHUTTERSTOCK



A chilling prophecy:
The heat death of the universe

BY ANNABELLE MATHERS, CIVIL ENGINEERING, 2022
DESIGN BY NICHOLAS BERRY, ENGINEERING, 2024

There are many theories on how the universe could end, with none of the scenarios being particularly warm and fuzzy. To construct those theories, experts tentatively apply the laws of physics to predict the behavior of objects and entities across the unimaginable expanses of space. In particular, the controversial prediction of universal Heat Death relies primarily on the second law of thermodynamics, which some experts believe will result in the eventual conversion of all life and matter—all of existence—into heat energy.

The main focus of the second law is entropy, or the measure of disorder in a physical system. In short, the law states that the total entropy within a closed system must always increase to some irreversible extent. Systems always seek to be in a more disordered state, therefore the total entropy of the universe displays continual, positive growth. In terms of energy, heat energy is more disordered than the mechanical energy involved in performing the work that produces the heat. Thus, the outcome of energy distribution in a system involving work always favors heat; there will always be more resultant heat energy than can be converted back into mechanical energy. Little by little, all working processes and forms of energy are being irreversibly converted to a more disordered state in the form of heat, all thanks to this systematic tendency toward increased entropy.

> "The overall temperature of the universe asymptotically approaches a temperature around absolute zero, giving the Heat Death its second name, the Big Freeze."

Such death by heat means that the universe may eventually contain no free, usable energy for thermodynamic processes or work. In other words, all energy may become heat energy in a universe going toward thermal equilibrium. By definition, heat is the transfer of energy, which requires areas or objects with different energy values. Without a transfer of energy, thermal equilibrium will eventually result in a loss of heat, further reducing the capability for thermodynamic activities that facilitate the existence of most biological life and matter. In achieving maximum entropy, the universe cannot perform any more work, nor physical processes requiring energy transfer. Ironically, equilibrium means the overall temperature of the universe asymptotically approaches a temperature around absolute zero, giving the Heat Death its second name, the Big Freeze. Whether or not the temperature of the universe will reach absolute zero, or simply a lower overall temperature than the current range of temperatures, is unknown, but the idea of universal cooling remains constant.

These phenomena rely on the theory that the universe expands and grows infinitely over time. However, the amount of entropy in the universe does not directly depend on this expansion. Instead, the expanding nature of the universe means the universe may not collapse prematurely into itself because of gravitational attraction, thereby providing enough time for the relatively slow conversion of all energy into heat energy. Within this period of time, stars may fade, black holes rise to prominence and then all disappear, and atoms decay, leaving nothing but a vacuum with some vastly separated photons and electrons.

It must be noted, some scientists refuse to assume that the very laws of physics that supposedly enable Heat Death apply unquestionably to the entire universe, especially with the amount of unknown and physically-befuddling aspects of deep space. Whether or not the universe can be considered a closed thermodynamic system, and how exactly the work done by gravitational systems affects entropy, remains questionable. Furthermore, different theories regarding the end of the universe and known life exist in the form of the Big Crunch, Big Rip, and Big Change, among others.

One feature all of these scenarios have in common is that the timespan over which they occur, and therefore the time until the universe becomes a thermodynamic circus, is relatively immense. Star fuel may not be depleted for another 120 trillion years, a timespan dwarfed by the 100 duodecillion (1040) years until subatomic particles decay. Last, but certainly not least, the black holes may evaporate after 100 duotrigintillion (10100) years. Scientists realize that this generous amount of time leaves room for continued speculation, and unforeseen nuances in universal physics. For those on Earth heading into the winter season, however, it may be at least a little comforting to speculate that the universe is, in fact, increasing in heat energy for the time being.

Reviews of Modern Physics (1997). DOI: 10.1103/RevModPhys.69.337
International Journal of Engineering Technology, Management and Applied Sciences (2015). DOI: 10.13140/RG.2.1.4158.2485

PHOTO BY KELLY CHAN, JOURNALISM, 2023

How do mood rings really work?

Physics, chemistry, and physiology rule out psychic forces

BY CATRYN ZHARYY, BEHAVIORAL NEUROSCIENCE, 2023
DESIGN BY IAN PROULX, BIOENGINEERING, 2022

The smallest piece of magic you can hold in your hand, a mood ring and its power to channel one's innermost emotions into trippy blends of color has charmed children and adults alike for close to 50 years. Since reaching peak popularity in the 1970s, the mood ring's selling point has always been that it mystically changes color depending on the temperament of the wearer. It might be easy to pass off the mood rings and necklaces that crowd out gift shops as just another kiddish gimmick; but, in fact, they are rooted in more science than crookery.

At the heart of mood ring "technology" is the unique chemistry and physics of liquid crystals. These naturally exist in a molecular state neither completely solid nor liquid. The components of liquid crystals tend to maintain their order similarly to the atoms of a solid, but can shift their orientation with a fluidity more like a liquid.

Materials which exist flexibly between normal states of matter are called mesogens. For each liquid crystal mesogen—the major types are thermotropics, polymerics, and lyotropics (used in soaps)—the particular chemical compounds that make up its molecules dictate the mesogen's physical, electronic, and optical properties. Furthermore, liquid crystal mesogens can exist in different molecular organizations called mesophases: the most common liquid crystal mesophases are nematic, cholesteric, and smectic. The "stone" in a mood ring is actually a hollow piece of glass or quartz filled with cholesteric thermotropic liquid crystals.

> "In a more passionate state, the body directs more blood to the surface of the skin, heating up the crystals and compressing the molecular helix, which in turn reflects shorter wavelengths of light like indigo and violet."

Nematic and cholesteric liquid crystals have similar formations; their molecules, characterized as "rigid rods," are randomly positioned but all point in the same direction. In a nematic crystal, the molecules in each layer point in the same direction as those in the adjacent layer. But as one moves through a cholesteric crystal, the direction of the molecules changes slightly—when all the layers are seen together, the molecules appear to organize in a helical manner.

The unique organization of a cholesteric crystal enables the circular polarization of light, giving mood rings their color. Light polarization occurs when a beam of light that contains lightwaves lying in different planes interacts with a medium which leaves it yielding lightwaves lying in only one plane. As light enters a cholesteric thermotropic liquid crystal, it is sequentially refracted through differently oriented layers of molecules, causing it to exit the crystal at different angles (this is the *circular* part of circular polarization). The varied direction of lightwaves minimizes wave interference and enables reflection and absorption of a diversity of light wavelengths, AKA colors.

So how can all this be manipulated to reflect something as abstract as a human emotion? Changes in emotion manifest themselves in changes in one's external body temperature. The base of the ring conducts heat to the cholesteric thermotropic liquid crystals, whose molecular helical organization twists in response. The resulting elongation or compression of the crystal "spring" structure enables the absorption of varying wavelengths of light.

In a neutral emotional state, the crystals hardly twist and naturally reflect blue/green light. In a more passionate state, the body directs more blood to the surface of the skin, heating up the crystals and compressing the molecular helix, which in turn reflects shorter wavelengths of light like indigo and violet.

In more alert states, ranging from excitement to anxiety, the body's physiological response is to direct blood away from the skin and toward the internal organs. The skin becomes colder, the "spring" in the crystals elongates, and the mood ring reflects longer wavelengths of light like yellow, red, and brown. Effectively, the mood ring-wearer is changing the color of liquid crystals with her brain (more specifically, the brain's awesome body-regulating abilities).

Of course, sometimes the body's temperature can change as a result of factors unrelated to emotion (simply being in a cold environment or releasing heat during exercise can tip off the crystals). But the mood ring's marketing is not so deceptive—to some extent, there is a real connection between one's mood and the colors that appear.

A child will explore and test out a mood ring to no end; it's only as age creeps in that a person abandons more and more of his curiosity for cynicism and exhaustion. Fortunately, it only takes some research and experimenting to come closer to the truth: that magic exists. Maybe not in a mood ring itself, but in the laws that dictate the natural world. And that thing a kid would call a magic trick is really what we call science.

Liquid Crystals (2007). DOI:10.1002/0470084030
Molecular Crystals (1969). DOI: 10.1080/15421406908084865
Optical Materials (2015). DOI: 10.1016/j.optmat.2015.07.010

SPONTANEOUS HUMAN COMBUSTION

We didn't start the fire (or did we?)

BY KAELEN ENCARNACION, BIOLOGY AND ENGLISH, 2021
DESIGN BY LILLIE HOFFART, ENVIRONMENTAL SCIENCE, 2022

The door handle's still warm. The air smells of something acrid and burnt. The wallpaper is blackened and peeling, with trapped air half-forming bubbles underneath. Bits of ash and other nondescript debris float in the air and settle on every surface, threatening your lungs with every breath you take.

This scene is all too familiar and all too tragic. Firefighters and police officers survey the landscape searching for a source of ignition – a blown outlet, a recently-lit fireplace, a spilled bottle of alcohol, or even a discarded cigarette. In most circumstances, a cause is identified and, somberly, the case is closed.

But sometimes, no external source of ignition is found. And sometimes, there are no human remains, save for a pile of ashes and a limb. Everything outside the immediate vicinity remains untouched, even though the victim must have burned at least 1600 degrees Fahrenheit for several hours to be reduced to nothing but ash. This terrifying phenomenon is called "spontaneous human combustion," or SHC.

Reports of this phenomenon have been recorded as early as the mid-17th century, with depictions in artwork dating from even earlier. However, SHC did not reach widespread public awareness until 1853, when Charles Dickens wrote about the death of a character by spontaneous combustion in his book, "Bleak House." Since then, SHC has found its way into literary works by authors such as Mark Twain, Herman Melville, and Washington Irving.

Unfortunately, SHC is not only seen in old myths or works of fiction.

The first highly-publicized case was that of Mary Reeser, a 67-year old woman found burned to death in her apartment in St. Petersburg, Florida, in 1951. All that remained was her left foot, a piece of vertebrae, and a shrunken skull. Little else showed any fire damage besides the chair she was sitting in and a nearby electrical outlet.

Another famous case was that of Dr. John Irving Bentley, whose right foot was found in his bathroom in 1966, while his ashes were in the basement below after the fire burned a hole in the floor. It was initially speculated that he dropped hot ashes from his pipe onto his bathrobe, igniting the wooden matches he kept in his pocket; however, his pipe was later found beside his bed.

SHC has even been observed within the past decade, with the mysterious death of Michael Faherty in 2010, whose badly burnt body was found on its back with his head next to an open fireplace. The only damage was that sustained by the body, the floor beneath him, and the ceiling directly above. After thorough investigation, officials concluded that the fireplace was not the cause of the blaze.

With around 200 alleged cases reported worldwide and such little evidence to explain otherwise, "spontaneous human combustion" has become an official coroner's verdict as the cause of death.

Over the past few centuries, many pseudoscientific explanations have sought attention in the wake of these "spontaneous" deaths. Just a century ago, SHC was attributed to moral failing: the victim must have been an alcoholic who saturated his body with liquor and received divine punishment. Some other theories suggested SHC was caused by poltergeist activity, or by fabricated subatomic particles called "pyrotrons."

Many scientists are unsurprisingly skeptical. While the human body's most flammable components are methane gas and fatty tissues, its 60 percent water content makes it difficult to ignite. When analyzing the reported cases, a few common threads seem to emerge: many of the victims were elderly, close to a fire source, were last seen smoking or drinking, and there were no witnesses around. They could have easily suffered from a heart attack or stroke and would be incapacitated if their clothing caught fire.

" With around 200 alleged cases reported worldwide and such little evidence to explain otherwise, "spontaneous human combustion" has become an official coroner's verdict."

This leads to the question of how the victims seemed to burn almost completely to ash while the surrounding area was untouched. The "wick effect," a well-observed phenomenon tested with a dead pig wrapped in a blanket, is when a part of the victim's clothing catches on fire and is sustained by the melted human fat it has soaked up. This turns the body into a morbid candle, where the clothing acts as the "wick" and human fat serves as the fuel source, creating a slow, potent burn.

While not every case of SHC is the same, its rarity, exclusivity to humans, and lack of scientific evidence all point to the verdict that the "spontaneity" in human combustion may just be smoke and mirrors.

Forensic Science, Medicine, and Pathology (2016): DOI: 10.1007/s12024-016-9748-2
Journal of burn care and research (2012): DOI: 10.1097/BCR.0b013e318239c5d7

PHOTO BY SHUTTERSTOCK

Ice planet or lava world:

Exoplanet environments depend on temperature

BY ISABEL KAIN, PHYSICS, 2021

Exoplanets are distant, mysterious cousins of our own home—obscure balls of rock and gas orbiting stars hundreds of light years away. It's difficult to understand what might be on the surface: are they covered in global oceans? Made up of molten lava? Does it rain razor-sharp shards of glass at thousands of miles per hour? (All of these examples, by the way, are current hypotheses about actual exoplanets). Constructing a story of what an exoplanet might look like is a complex process, but it starts with one simple question: how hot is it?

Surface temperature is one of the most fundamental shaping factors of a planet, where even small shifts can result in dramatically different environments. To use Earth as an example, the difference between the coldest and hottest temperatures ever recorded (in Antarctica and California respectively) is only 265°F. By the standards of a human body this might seem like an enormous difference. But the universe works on very different temperature scales: between the cold of space at −454.81°F and the temperature of the hottest astronomical body in the neighborhood (the Sun, which is nearly 10,000°F at its surface), anything is fair game.

The importance of heat comes down to phase changes. Materials have a characteristic threshold temperature at which they transition from one phase to another, like how liquid water will freeze into solid ice when cooled below 32°F at sea level. The phases of materials on a planet's surface can define what that environment looks like: an ice-covered world is fundamentally different from a hot, gassy one; a planet hot enough to have molten rock is very different from a temperate ocean world.

Precisely mapping exoplanet surface temperatures is near impossible even with the fantastic resolution of current telescopes, but estimates can be calculated from the characteristics of the planetary system. The first temperature assessment is derived from the heat of the star. A star produces heat through fusion reactions at its core, where light elements such as hydrogen or helium are fused into new, heavier elements, releasing explosions of excess energy. The more actively a star is fusing elements, the more energy is produced and the hotter it burns.

This heat actually changes the way stars look, allowing astronomers to estimate temperature simply using color: cooler, smaller stars appear red, even to the naked eye, and hot massive stars appear blue. Just by looking at a star, we can estimate the amount of heat that any orbiting planets might be exposed to.

The amount of heat that is actually delivered to the planet's surface is determined by its orbit. Generally, a close-in orbit will create a warm world, whereas a wide orbit creates a cooler one. But in some special cases, planets experience both extremes. Most observed planets have an elliptical orbit, spending only a brief moment close to its star before being slingshot farther into space. Changes in stellar irradiation over the course of its orbit can cause drastic shifts in temperature, subjecting the planet to fiery heat at closest approach and freezing cold at greater distances. These huge swings in temperature can drastically disrupt any weather or climate equilibrium on the surface, wreaking havoc on any potential habitability.

Things get really interesting when a planet has an atmosphere, which will accumulate if the planet is massive enough to gravitationally attract enough gas in its neighborhood (and far enough that it's not burned off by its star). This envelope of gas acts like an insulating blanket, trapping heat from the star and distributing warmth around the entire planet. Without this distributive effect, heat would be concentrated on the star-facing side of the planet, resulting in a crispy dayside and a freezing night side. Movement of particles within the atmosphere triggered by this distribution of heat creates a dynamic global climate—and this dynamic nature is what makes surface temperature so difficult to precisely characterize.

When we dream of these distant worlds, we envision the shape of mountains, the vast expanses of oceans, perhaps even ecosystems of alien life. Characterizing exoplanet surfaces is a feat of technology still just out of reach – precise observations and sophisticated software models are enough to build amazing hypotheses, but don't yet give definitive answers. As our telescopes and our knowledge of planetary systems grow, we may soon be able to peer onto these planets' surfaces, and see worlds more amazing than we can imagine.

DESIGN BY KYLA VIGDOR, DESIGN, 2021

PHOTO BY SHUTTERSTOCK

Too hot, too cold

The argument over the perfect office temperature heats up

BY LILLIE HOFFART, ENVIRONMENTAL SCIENCE, 2022

The A/C vent blasts frigid air down from the ceiling. You are at your desk at co-op and wish you brought a second jacket; there is no way you can concentrate in the chill. You bring your project home after work, but just the opposite is the case at your dorm. The radiators are on full-blast, and there is no way you are getting work done here, either.

According to the Occupational Safety and Health Administration (OSHA), which oversees workplace safety standards, the temperature in any office workspace should fall within 68 to 76 degrees Fahrenheit. This temperature range is calculated to ensure "thermal comfort" to the greatest number of employees. This means that an employee wearing a normal amount of clothing should feel neither too cold nor too warm. However, this recommendation is based on studies from over 30 years ago; OSHA references studies that took place from 1981 to 1988. Since then, the workplace has changed and it's time for an update.

Women make up a considerable part of the workforce. From 1985 to 2015, the number of women in the civilian labor force increased by over 23 million, according to the US Department of Labor. It is well-documented that women perform better in warmer temperatures but men prefer colder temperatures, and as demographics shift, there is no longer a one-size-fits-all answer for the office climate. As demographics of the workplace change, the recommendations for how to most efficiently run a workplace should also.

It has been repeatedly affirmed that people's performance is affected by temperature, even more incentive to act on this issue. According to a 2004 study from Cornell University, the difference between working in a workplace with good and poor thermal comfort adds up. The study compared typing efficiency at 68 degrees and 77 degrees. At the chilly temperature, workers were typing 54 percent of the time with a 25 percent error rate, while at a more comfortable 77 degrees, they were typing 100 percent of the time with a 10 percent error rate. Researchers estimated that keeping a workspace at a more comfortable temperature could save employers about two dollars per worker per hour.

> "Environmental factors, like temperature, have a much bigger impact on your day-to-day lives than we generally give them credit for."

A study by Tom Chang and Agne Kajackite published in May of this year investigated the difference temperature plays in the performance of men versus women in office-like tasks. The study took over 500 participants and placed them in rooms with a range of temperatures—from 60.8 to 91.4 degrees Fahrenheit. The subjects were then tasked with math (adding numbers), verbal (rearranging letters into words), and cognitive (solving logic puzzles) tests. The performance results were then analyzed with respect to temperature.

As expected, women's performance went up with an increase of temperature, and men's performance decreased, though women were significantly more affected. A two degree increase in temperature resulted in a 1.76 increase in math accuracy in women. On the other hand, men performed with a statistically insignificant 0.63 decrease accuracy. Verbal tasks followed the same trend, and cognitive tests were not affected. The warmer the room, the more efficient overall work was completed, given an equal gender distribution.

However, in an interview with NPR, Chang said the main takeaway from this experiment wasn't simply that office temperatures should be warmer.

"I think, if anything, what I want people to take away from this study is that we're all a little different here and that one size doesn't fit all," he said. "More broadly, I think we should be more aware that environmental factors, like temperature, have a much bigger impact on your day-to-day lives than we generally give them credit for."

Instead of one person controlling the thermostat, causing workers to sweat through their shirts or pile on the sweaters, temperature should be an easily adjustable and not a one-size-fits-all solution. This will not only improve productivity, but also the overall comfort of the employees.

PLoS ONE (2019) DOI: 10.1371/journal.pone.0216362
Building and Environment (2007) DOI:10.1016/j.buildenv.2006.01.009

PHOTOS BY SHUTTERSTOCK

Can you feel the love tonight? It's all in your brain

BY BINH DANG, ECOLOGY AND EVOLUTIONARY BIOLOGY, 2022

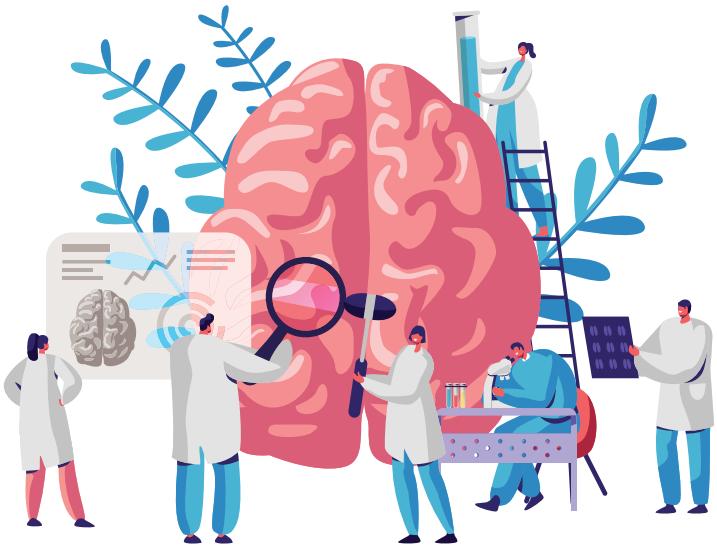
DESIGN BY KYLA VIGDOR, DESIGN, 2021

Love can make you feel all warm and fuzzy inside, like you have butterflies in your stomach, or like your heart is racing a million miles an hour. You love with your heart, right? You love someone with a big heart, they can make your heart skip a beat, or they could break your heart. While the heart is associated with love, it's the brain pulling the strings. Love is a powerful force that can change your physiology drastically, but it's all in your head. At least, it starts there.

With thousands of love songs, romance novels, and romantic comedies, it seems like love is a complex feeling that's an indescribable and unique experience that a person has individually. However, scientists at Rutgers University, led by Dr. Helen Fisher, have broken it down into just three categories and seven hormones.

Lust is the first phase, and it has its roots in evolution and uses the hormones testosterone and estrogen. A desire for sexual gratification propagates the act of reproduction, which all species do. The intent is for organisms to produce offspring to continue the proliferation of parental genes and the species as a whole. When a person meets someone they are romantically interested in, their hypothalamus, which is the main hormone regulator in the brain, stimulates the production of testosterone and estrogen in the reproductive glands—the testes and ovaries. Testosterone and, to a lesser extent, estrogen increase libido in both males and females, despite the misconception that those hormones are exclusive to each sex. Some women have reported an increased sex drive while ovulating (when estrogen levels are the highest).

Attraction is the second category of love and happens in the first few weeks or months of a relationship. During this time, a person might feel lively, exuberant, and infatuated. This phase of love involves the brain's "reward" pathway, which is dominated by the infamous dopamine—most commonly known as the "pleasure molecule." When one does something that feels good—spending time with a romantic partner, for instance—dopamine is released by the hypothalamus. This dopamine release makes you feel rewarded and want to seek out that reward again; think, for example, about the pleasant sensation you might get when you take a bite of your favorite food or when you hear a funny joke. The phrase "love is a drug" isn't entirely wrong either; they activate the same dopamine pathways in the brain.



Combined with another excitatory hormone, norepinephrine, your body goes through the greatest physiological changes associated with love. Norepinephrine is one of the main hormones involved in the fight or flight response, and when you are in love, it has the same effects on your body. You're more alert, your body temperature increases, your pupils dilate, and your heart beats faster. Your digestion also slows, so you may experience gastrointestinal discomfort. In other words, that warm feeling you get when you're in love and nervous might be heartburn.

> "The phrase 'love is a drug' isn't entirely wrong either; both activate the same dopamine pathways in the brain."

The final molecule involved in attraction is serotonin. Attraction actually decreases levels of serotonin, which is associated with the strong infatuation present in the beginning stages of love. This is believed to be the correlation because people diagnosed with obsessive-compulsive disorder are also associated with having low levels of serotonin, hence the obsession over a romantic partner.

The last phase of love is attachment. Unlike the other two categories, this one is also involved in other types of social relationships, not just romantic ones. The dominant hormones propagating attachment are oxytocin and vasopressin. Oxytocin is colloquially known as the "cuddle hormone" and is released by the hypothalamus during sex, childbirth, breastfeeding, and hugging. These seem like a disparate set of activities, but any event that involves bonding increases oxytocin levels. The release of vasopressin is also associated with pair bonding, though to a lesser extent than oxytocin. At this phase, the other hormones are less prevalent in the body, and oxytocin and vasopressin predominate.

This deconstructed view may seem to undermine the grand idea of love, but there are still many questions that need answering to fully understand it. There's no denying the feel-good emotions love can cause, so we should be grateful for the influence these tiny molecules have on us. The next time you give a loved one a hug, embrace the influx of oxytocin you receive. It's called "having chemistry" after all.

PHOTO BY SHUTTERSTOCK

Acting like a dog in heat?

More like a human in oestrus

BY MAYA KRAUSE, ENVIRONMENTAL SCIENCE, 2022

DESIGN BY KATIE GREEN, BIOENGINEERING, 2022

Some people like to believe our species has evolved away from more primitive behaviors, but when it comes to reproduction, we may not be so different from other animals. Most female mammals have a time period in their reproductive cycle called heat, when they are the most sexually receptive and prepared to mate, which occurs just before ovulation. The hormones produced by the animal at this time increase sexual receptivity, which are behaviors and other characteristics that assist the female in fertilizing her eggs. In the scientific community, this phase is called oestrus. Different animals express oestrus in different ways; for example, female dogs give off an odor that attracts male dogs to her, and female cats will tilt the back of their pelvis up in a position called "lordosis," which aids in reproduction.

It was long thought that humans had evolved away from the oestrus phase and that women no longer have hormonal shifts that result in behaviors related to sexual receptivity. The thinking went, because women have lost oestrus, they are potentially constantly sexually receptive and are able to be impregnated at any time during their reproductive cycle. The leading theory as described by Heistermann et al. states that humans lost oestrus in order to conceal paternity and reduce infanticide by male partners. If a woman is able to be impregnated at any time, and she has multiple partners, there would be no way for early human males to know whether the child was his offspring or not, and would be less likely to kill the child for not being his.

> "Recently, however, the theory of human females losing oestrus has been called into question."

Recently, however, the theory of human females losing oestrus has been called into question. According to Steven Gangestad and Randy Thornhill from the University of New Mexico, women's sexual desires change during the part of the menstrual cycle when they are most fertile. In particular, women are more selective towards traits that ancestrally connoted male genetic quality and high testosterone (strong jaw, dominant behavior, deep voice, tall height) when they are in the fertile part of their menstrual cycle as opposed to when they are not fertile.

Additionally, Haselton et al. found that women dressed more attractively or provocatively when they were near ovulation. The changes in desires are not isolated to tendencies towards male traits, either. Lisa Diamond and Kim Wallen found that women who identified as lesbian showed increased interest in sexual contact with women when they were ovulating. These shifts indicate that sexual receptivity increases when a woman is in the fertile part of her cycle—evidence that women have retained oestrus.

Fortunately, all hope is not lost for heterosexual men without traits that indicate high testosterone. Gangestad and Thornhill's research found that fertile women seek out men with such traits as short term partners. There was no change across the cycle in women's attraction to men who they perceive to be intelligent, kind, or financially successful. This research suggests that women in oestrus are more interested in sex for lust as opposed to intimacy or emotional connection.

The theory proposed by Heistermann et al. for why humans lost oestrus is not discarded in Gangestad and Thornhill's research. In fact, Gangestad and Thornhill wrote that women's cycles have evolved to be able to conceal paternity while also being selective. If a woman is able to have multiple partners outside of her most fertile time period, but maintains selectivity when most fertile, she can increase the chances that her offspring will have the most desirable traits while decreasing the chances that her offspring will be killed by another mate. This exact pattern was observed in human's closest relative, the chimpanzee, by Rebecca Stumpf and Christophe Boesch.

Contrary to prior beliefs, women's desires while fertile play a large role in selectivity and reproduction. Evolutionarily, oestrus served to increase the chances of birthing a child with genetically desirable traits who would not be killed by a non-parental male. Today, these selective behaviors lead to fertile women seeking out short term relationships more readily. While humans do not express their lust as blatantly as cats and dogs, it is clear that women have not lost the sexual receptivity that comes with being in heat.

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DR. PEPPER

BY HEATHER WELCH, ENVIRONMENTAL SCIENCE, 2020

What do hot chili peppers, wasabi, and scorpion venom all have in common? They make you go "ouch"—but why? Dr. David Julius, a professor of physiology at the University of California, San Francisco, was awarded the prestigious Breakthrough Prize in Life Sciences this year for his research on this topic.

The decades of research done by Julius and his colleagues led up to their discovery of the importance of transient receptor potentials (TRPs) in the perception of pain and temperature. TRPV1, the TRP involved in the perception of chili peppers, is a protein that sits on the surface of nerve cells. As an ion channel, it remains closed until something activates it. The capsaicin in chili peppers activates TRPV1 and allows ions (sodium and calcium) to enter through the channel. Once the ions have entered, neurons travel through a relay from the periphery—wherever you touched the hot chili pepper—up through the spine and to the brain, where the signal is translated as a painful burning sensation.

Interestingly, TRPV1 is the TRP that is involved in actual heat perception; the reason that it also detects chili peppers is that the vegetable long ago evolved to mimic a heat stimulus in order to fend off predators. TRPV1 is also activated by compounds from other plant and animal species, such as lemons and some spider venoms, and can detect some chemicals that the body produces in response to inflammation.

Julius has studied other related channels—one of them being TRPA1. Julius refers to TRPA1 as the "wasabi" receptor because it is the channel that responds to the compounds in wasabi to trigger that strange sensation when just a little bit too much has been consumed. WaTx, a toxin emitted by the black rock scorpion, was discovered by Julius's team to be a novel activator of TRPA1 in that it elicited physical behaviors from the ion channel that were distinct to the toxin. This identification may prove to have pharmaceutical and therapeutic value as there is now a known compound that can be used to alter the state of TRPA1 and improve inflammatory responses in patients.

> "Research is currently being done on the potential of TRPV1 and similar molecules such as TRPA1, as analgesic sites, particularly for conditions such as arthritis and other inflammatory diseases."

The growing knowledge of pain, as well as the molecules and neurofibers involved in it is exciting; it is easier to develop a treatment approach to pain when its molecular causes are known. Research is currently being done on the potential of TRPV1 and similar molecules such as TRPA1, as analgesic sites, particularly for conditions such as arthritis and other inflammatory diseases. This is due to the inflammatory indicators that the molecules detect and their role in pain hypersensitivity after injury.

Other channels are also being discovered as useful in the treatment of pain. A team of researchers studied the sodium channel Nav1.7, focusing on how to emulate mutations that cause pain indifference in humans. Because of the effect of these mutations, compounds that inhibit the channel would be advantageous as analgesics for treating pain. The researchers identified a peptide extracted from centipede venom, Ssm6a, that "potently and selectively blocks the human Nav1.7 channel." In rodent models, the peptide was more effective than morphine as an analgesic. The opposite of TRPV1—TRPM8—is involved in real cold perception and is triggered by the menthol in mint. Activation of the channel may be used to mechanically produce analgesia in chronic pain sites.

Though exciting research is happening, development in medicine and pharmaceuticals is always slow and faces many obstacles. For instance, the development of treatments involving the chili pepper TRP is slowed down by the fact that in some cases, treatments targeting TRPV1 inhibit patients from sensing noxious heat, which is dangerous to health. Obstacles, of course, are meant to be overcome; perhaps someday soon, arthritis may be safely alleviated by pharmaceutical control of the TRPV1 channel.

Toxicon (2012) DOI: 10.1016/j.toxicon.2012.04.336
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PHOTOS BY PIXABAY AND SHUTTERSTOCK

Drought, fire, and floods:

Focusing on those suffering from climate change now

BY GABRIELLE HERNANDEZ, BIOCHEMISTRY, 2022

Climate change is an impending challenge that most people think of on a daily basis. Between metal straws and reusable cups, the general population has been increasingly attempting to do what it can to save the oceans and clear the air, whereas the majority of emissions is produced by government and privately-held oil and energy companies.

It is difficult to fathom the impacts of the data that is released everyday about climate change forecasts. Modest projections for the United States place the cost in the billions, accounting for health, infrastructure, and ecosystemic impacts. Two-thirds of the world's urban populations are threatened by rising sea levels. The city of Boston has already started to dedicate time and money to a city-wide climate change preparedness initiative in response to projections that show much of Boston's coastlines submerged in extreme cases. As a product of rising sea levels, 630 million people worldwide are predicted to be threatened by flooding and high tides by the year 2100.

These predictions are not just a dystopian outlook on the ever-nearing future. To some of the most vulnerable populations in the world, this is happening now. Around the world, people are facing a diversity of extreme threats brought on by climate change that are pushing them out of their homes. Many island and coastal nations experience near-constant flooding and tropical storm threats.

The Middle Eastern, Latin American, and Sub-Saharan regions are among the most threatened due to populations that are highly dependent on the climate for their survival. Drought in Guatemala, El Salvador, and Honduras has contributed to instability in these regions, forcing people to migrate elsewhere to escape food shortages and increased violence. While wildfires rage on in Brazil due to both drier seasons and human-led deforestation, indigenous populations that have existed in these regions for centuries are forced out of the land by both these natural and man-made disasters. Internal migration as a result of climate change has increasingly become a crisis that lawmakers will be forced to reckon with as they play judge and jury for millions around the world seeking asylum.

Despite these current conflicts, international, federal, and state policy is falling behind in redefining what it means to be displaced by climate-related pressures. Without clear-cut policy, many people displaced by flooding and droughts are left without the international protections given to other refugees fleeing violent conflicts in their homelands. This is set to change, though.

In October, Senator Ed Markey of Massachusetts introduced legislation to reword the United States' policy on refugees to include those displaced "for reasons of sudden or progressive change in the environment that adversely affects his or her life or living conditions." The legislation also proposes a 10-year long strategy to deal with the progressive impacts of climate change on the American people. Although this legislation is not likely to pass the Republican-held Senate for some time, it brings attention to the fact that people displaced by climate change are not protected or supported by outdated policy.

Recently, on Northeastern University's campus, the Latin American Student Union (LASO) hosted an event called "Climate Crisis in Our Communities and What to Do About It" analyzing the humanitarian impact of climate change on Latin American populations. The members of the club discussed environmental racism—the idea that issues of climate change and environmental destruction disproportionately impact communities of color. Their presentation also emphasized how migration as a result of climate change will be a large portion of the refugees coming from the Southern border.

The Coalition Coordinator for LASO, Luis Sanchez, commented, "I think it's important to note that soon, these refugees will come not from other countries, but within a country itself. This will expose the hypocrisy behind the term 'illegal aliens.'"

Furthermore, on the topic of accommodating asylum-seekers, Denisa Ramseier, Vice President of External Affairs for LASO, commented, "I personally feel that while we should always try our best to lend a hand to refugees in general, we almost have a responsibility to help climate refugees as the climate crisis is global and one that the United States has continuously contributed to for years on end." Ultimately, climate refugees who are already being affected by the warming planet will need to be accounted for as the sociopolitical challenges of Central and South America increase.

> "To some of the most vulnerable populations of the world, this is happening now.

Preparing for the future is challenging and sometimes incomprehensible, but aiding those who are already losing their livelihoods to climate change should be a priority now.

Carbon Emissions by Companies (2013). DOI: 10.1007/s10584-013-0986-y
High Sea Levels and Displacement (2019). DOI: 10.1038/s41467-019-12808-z

DESIGN BY LILLIE HOFFART, ENVIRONMENTAL SCIENCE, 2022

PHOTO BY SHUTTERSTOCK

THE SCHMIDT STING PAIN INDEX

BY CERINA KARR, BIOLOGY, 2023

DESIGN BY MARISSA KEESEY, ELECTRICAL ENGINEERING, 2022

Almost everybody can recall the first time they were stung by a bee. The sharp pain and soreness that follows a bee sting is enough to render any child in tears. How, though, does the sting of this tiny furry insect compare to something more exotic, such as the tarantula hawk wasp? The name itself is terrifying. Yet, an entomologist by the name of Justin O. Schmidt willingly subjected himself to thousands of stings in order to rank the relative pain of different stinging insects.

The Schmidt sting pain index is a scale that ranks the pain of hymenopteran stings. Hymenoptera is the order of insects that includes wasps, bees, and ants. The scale goes from zero to four, with zero meaning the sting is ineffective against humans and four being the most intense pain. While many of the insects included on the scale may appear small and harmless, Schmidt would assure you that appearances can be misleading. He asserted that Paraponera clavata, or the bullet ant, has the most painful sting out of all observed hymenoptera. The bullet ant and the tarantula hawk wasp were rated a four.

The main focus of Schmidt's early research was to determine relationships between a sting's lethal toxicity, hemolytic activity, and "algogenicity," or ability to cause pain. Hemolytic activity refers to the venom's destruction of red blood cells. The purpose of Schmidt's scale was to quantify algogenicity in order to relate it to the other two properties. Interestingly, Schmidt found no correlation, suggesting that further research was needed to understand the role of hemolysins in venom.

Since the scale is based on Schmidt's subjective experience, it may not be entirely accurate; the degree of pain may vary from person to person. However, in addition to ranking the sting pain, Schmidt provided detailed descriptions of each sting, since different insects may inflict different kinds of pain. For example, after getting stung by Pogonomyrmex badius, the Florida harvester ant, Schmidt wrote: "This extreme pain lasted 4-8 hours and may be likened to pain that might be caused by someone 'turning a screw into the flesh' or 'ripping muscles and tendons.'" Although Schmidt's scale is subjective, I think we can all agree that we will take his word for it.

In contrast, Schmidt described stings ranked a "one" on his index as "light, ephemeral, almost fruity. A tiny spark has singed a single hair on your arm." (It makes sense that a man who has experienced the long, excruciating pain of a bullet ant sting might describe a bee sting as "fruity.")

Logically, one would be wise to avoid the bullet ant, unless you're as wildly curious as Schmidt. However, the Sateré-Mawé tribe living in the Amazon Rainforest uses the bullet ant's sting as a rite of passage for men. Hundreds of ants are woven into a glove, and boys must wear the glove for five minutes as they are stung repeatedly. Hours of excruciating pain ensue, often accompanied by disorientation and confusion. Men in this tribe usually go through this ritual at least 20 times throughout their lives.

People seem to be fascinated by stories of pain or danger. Is it because humans enjoy it when others get hurt?

Schmidt theorizes that our fascination with the extreme stems not from an inherently sick or twisted nature, but rather from evolution. People naturally want to learn about potential danger so that they can become knowledgeable enough to avoid them. Although many painful insect stings are not actually lethal, pain is our body's way of signifying potential damage. Stings are unpleasant to read about, yet it is in our nature to want to learn about it to enhance our long term survival. Accordingly, Schmidt believes his research has applications in human psychology: "It provides a window into understanding ourselves, how we evolved to where we are, and what we might expect in the future."

Archives of Insect Biochemistry and Physiology (1984). DOI: 10.1002/arch.940010205

Hard boiled eggs and well-done meat:

What's a protein to do?

BY SARA GANNON, BEHAVIORAL NEUROSCIENCE, 2021

DESIGN BY KRISTI BUI, COMPUTER SCIENCE, 2021

Most people are familiar with the concept of proteins, an essential nutrient that is found in foods like eggs and meat. But what *are* proteins and why do foods that are high in them change so drastically when cooked?

Proteins are complex molecules composed of a long chain of amino acids, which serve as building blocks. Each protein is distinct not only in the order of amino acids, but the unique formation created when you have hundreds, or thousands, of amino acids bonded together. The molecular interactions between these amino acids creates coiling and folding, giving proteins their unique structures. This structure is what allows a protein to have a specific function. For example, the shape of an enzyme's active site must match the shape of its target substance, or substrate, in order to properly recognize the correct substance.

It follows that the change in the structure of a protein would lead to the loss of that protein's specific function. This process is called denaturation, and can be caused by external stress on the protein, such as a large shift in environmental acidity, salinity, radiation, or heat. For example, when a protein is exposed to a sufficient increase in temperature, it will unfold into just a single strand of amino acids. While heat causes the arrangement or structure of the protein to change, it allows the order of the amino acids to remain the same.

So why is this important? It's believed that the denaturation of proteins is a mechanism that determines many biological laws that we take for granted. For example, it explains why a high fever is so dangerous. The explanation is in the proteins; temperatures above 105.8°F are sufficient to break molecular interactions between amino acids and denature proteins, leading to significant changes in protein shape and function, potentially rendering them unfunctional. A fever of 106°F has the potential to be deadly, considering proteins make up not only your skin and muscles, but also the digestive enzymes in your stomach and the antibodies that protect your body from viruses and disease.

Aside from the dangers, there are also interesting and useful interactions that can occur during protein denaturation. For example, think about how fresh pineapple tastes — it has a bit of bite, and sometimes you even experience a slight burning sensation on your tongue or in your mouth. This is because the fruit contains a protein called bromelain, which functions to break down other proteins. So when you're eating pineapple, it actually tries to eat you back! Now think about how pineapple tastes once it's been cooked — sweet and devoid of any burning sensation. This is because through the process of cooking, heat has denatured the proteins in the pineapple. The bromelain has been broken down and its function rendered useless.

Moreover, proteins and their denatured qualities can serve some very important roles in modern-day cooking. For one, they are an excellent binding substance. The reason that eggs are used in most baking recipes, such as cake or cookies, is because as the proteins denature, the unraveled strands bind and stick together to form a matrix-like network throughout the substance. This network of denatured proteins provides structure and uniformity throughout the baked good.

Another great example of the use of denatured proteins is when fish is cooked using acidity (and no heat)! The acidity alone functions as an environmental stressor strong enough to unravel the protein structures and sufficiently "cook" the fish. The proteins become denatured just as they do with exposure to heat.

Taken these examples, it's quite evident that proteins, in their denatured form and otherwise, serve an important role not only in the lives of humans, but in all of biological life. And scientists agree — there are many groups studying and pushing the boundaries of natural protein law. When you think of a hard boiled egg or cooked meat, it seems quite obvious that a molecular change like that is irreversible. However, scientists have recently discovered evidence that

> "...when you're eating pineapple, it actually tries to eat you back!"

it's not. In 2015, researchers at the University of California Irvine discovered a way to un-boil an egg. One characteristic of denatured proteins is the tangling of long chain of amino acids, and this scientific group successfully reversed the protein tangling by using a vortex fluid device. A discovery such as this one might not mean much to cooks, but could serve to reinvent scientific strategies in the field of molecular biology.

Journal of Food Processing and Preservation (1994). DOI: 10.1111/j.1745-4549.1994.tb00240.x
Biochemistry (1994). DOI: 10.1021/bi00207a018

PHOTO BY SHUTTERSTOCK

Zombies in the snow:

Reviving ancient pathogens

WRITTEN BY AMANDA ZAVALA, CELL & MOLECULAR BIOLOGY, 2020
DESIGNED BY IAN PROULX, BIOENGINEERING, 2022

Siberia 2016. The summer was unusually warm, and the permafrost began to melt, thawing reindeer carcasses that were buried in the ice 75 years ago. That summer, a young boy, and over 2,000 reindeer, died of anthrax infection—the first Siberian outbreak in 75 years.

Permafrost is a layer of soil and ice that remains frozen year-round, covering almost a quarter of the Northern Hemisphere. In northern Siberia, the permafrost can be up to 1,500 meters thick, with fluctuations of about 50 centimeters depending on the season. In the summer of 2016, temperatures in Siberia reached a record high, and thawed an unusually large amount of the permafrost. This thawing released *B. anthracis*, or anthrax bacteria, which had lain dormant in frozen reindeer carcasses, into the water supply. As early as 2011, Russian scientists predicted this outbreak based on the steadily rising global temperature since the 1970s, and the correlated thawing of permafrost. Some experts theorize that, as the global temperature continues to increase, more ancient pathogens will emerge and become infectious again. Media reports on the phenomenon have coined the term "zombie pathogens" to describe the potential risk of these dormant microbes.

> "That summer, a young boy and over 2,000 reindeer died of anthrax infection – the first outbreak in Siberia in 75 years."

Anthrax is not the only microbe that can be revived from frozen samples. Once thawed, 32,000-year-old bacteria, found in a frozen pond in Alaska, were metabolically active. Ancient viruses were also recovered from Siberian ice samples. These microbes, which do not infect humans, were so old that they had not been seen since wooly mammoths were alive. Not all microbes are able to survive cold temperatures for long periods of time, but the microbes that developed to be especially hardy could survive. Under harsh conditions, cold-resistant bacteria, like the *C. pleistocenium* identified in Alaska, form tough spores that can survive for over a century. Modern spore-forming bacteria include organisms that cause tetanus and botulism. The viruses that, thus far, have been recovered from permafrost only infect amoebas, but experts suggest that viruses capable of infecting humans could be lying dormant as well.

Among all the other concerns associated with climate change, zombie pathogens are one not often considered. Fortunately, despite media concerns, the actual risk to humans seems low. Deliberate attempts to revive virus particles in the lab were unsuccessful in the past 50 years. On multiple occasions, scientists took samples from mummified bodies to try to culture everything from influenza to smallpox; nobody was able to recreate infectious particles from the recovered genetic material. If viruses cannot be revived under rigorous laboratory conditions, it seems unlikely that an outbreak could occur due to naturally thawing permafrost. The viruses that were recovered from ancient ice samples all belong to a class called giant viruses. This class contains viruses that are larger than the typical virus, and that use extra genes to encode a thick protein shell, called a capsid, which provides protection similar to bacterial spores. No discovered giant viruses are capable of infecting humans.

And the anthrax outbreak? While the Russian government attributed this outbreak to spores from reindeer carcasses, anthrax bacteria is found naturally in soil, and it is not impossible for the bacteria to enter the water supply in other ways. Revival from thawing permafrost is an unusual cause of outbreak, and scientists currently do not understand the phenomenon well enough to confidently predict how the potential frozen spores respond to continued rising temperatures. Many of the most concerning infectious diseases that could make a comeback are not capable of surviving when frozen because they are designed to survive and replicate at body temperature. Increasing temperatures will lead to a wide variety of global problems, but the risk of zombie pathogens emerging from frozen graves to infect us with long-forgotten diseases seems only slightly more likely than a classic zombie apocalypse.

PHOTO BY SAMUEL KLEIN, BIOLOGY, 2022

Thermoelectric materials

A balancing challenge for recycling heat

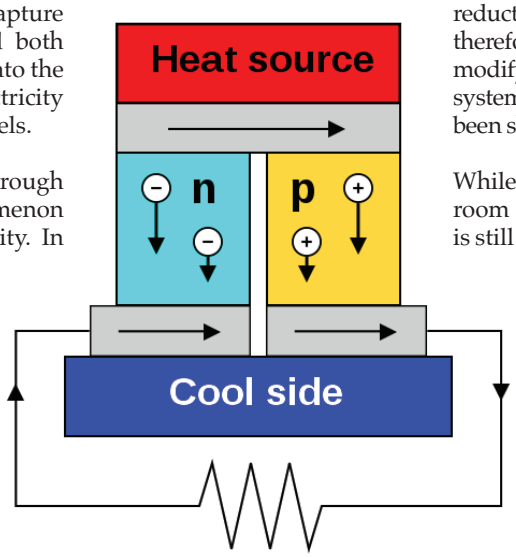
BY JENNIFER GARLAND, APPLIED PHYSICS & MATH, 2021

DESIGN BY KRISTI BUI, COMPUTER SCIENCE, 2021

As the planet warms due to excessive burning of fossil fuels, and as these sources deplete, much focus has been on researching alternative energy sources. While developing these more sustainable technologies is vital, an often publicly overlooked source of energy is the waste heat from processes already in place, such as from power plants, appliances, and cars.

Unfortunately, thermodynamics limits efficiency to less than 50 percent in these systems, and all of the waste heat is simply given off into its surroundings. Figuring out a way to capture and recycle this extra energy would both reduce the problem of releasing heat into the environment and replace further electricity that would be produced from fossil fuels.

One way to utilize waste heat is through the Seebeck effect, which is a phenomenon where heat is converted into electricity. In some n- and p-type semiconductors called thermoelectric materials, the application of a temperature gradient causes current to flow. When one side of a thermoelectric material is cold and the other is hot, electrons move from the hot to the cold side, and electric potential builds up. However, finding suitable materials has proven a challenge over the last few decades.



Three main properties characterize a good thermoelectric material: high electrical conductivity, low thermal conductivity, and a high Seebeck coefficient (S). The Seebeck coefficient of a material is the amount of voltage resulting from the temperature difference across the material ((S = -[?][?]V/[?][?]T)), so it is desirable to have a high coefficient, indicating extracting the most electricity from the least amount of heat. High electrical conductivity allows for easier current flow, and low thermal conductivity retains the temperature gradient. However, these two transport properties usually come hand-in-hand, making it difficult to find optimal candidates.

The current leading thermoelectric material, bismuth telluride (Bi_2Te_3), is already used in some small-scale generators and cooling devices. Bismuth telluride has been utilized in bulk, but lower dimensional materials such as thin films and nanowires allow for further reduction of thermal conductivity, and therefore higher efficiencies. Alternately, modifying existing bismuth telluride systems by doping with semimetals has also been shown to improve transport properties.

While bismuth telluride performs well at room temperature, the energy conversion is still limited to only 5 to 7 percent, and the elements are relatively rare and toxic, so more research is going into discovering and evaluating better materials. In September 2019, a study led by Wenke He of Beihang University was published in Science, presenting a new tin sulfide (SnS) based thermoelectric crystal that, if utilized, would reduce costs with earth-abundant elements.

Ultimately, the current efficiencies of the best-performing thermoelectric materials and generators are still too low to compete with existing power generation techniques. Teams like He's are hard at work creating, altering, and testing new ones, in hopes that we can find a way to make inevitable heat loss do some work for us.

Advances in Materials Science and Engineering (2018), DOI: 10.1155/2018/1210562
Science (2019), DOI: 10.1126/science.aax5123

PHOTO BY KEN BRAZIER

PHASE-CHANGE MATERIALS:

A sensible thermal solution

BY JULIA HINES, CHEMICAL ENGINEERING, 2021

DESIGN BY ANANYA DHANDAPANI, UNDECIDED, 2023

Thermoregulation is a process used in all facets of life—whether it is the sweat that drips off of you during a workout or the thermostat in your dorm that may (or may not) actually change the temperature in your room. Regulating temperature keeps humans alive and keeps many appliances safe. In the past decade, many advancements have been made to find newer, cheaper ways to thermoregulate. Research into phase-change materials (PCMs) has opened a new door in thermoregulation, allowing latent heat transfer, that is, heat transfer without any change in temperature (ie. phase change), to be used in addition to sensible heat transfer—heat transfer that results in a temperature change.

Phase change materials are broadly defined as substances which absorb or release high amounts of latent heat when they go through a physical state change (solid to liquid, liquid to gas, etc). Latent heat transfer is energy transferred into a substance without any change in temperature. This most commonly signifies a phase change occurring. Sensible heat transfer is energy transferred that results in a temperature change. Using latent heat transfer, PCMs are able to store more energy per unit volume than materials that use sensible.

This property of PCMs can be used in multiple ways, whether it is thermal energy storage that can be used for another process, or as a thermal barrier or insulation.

With the move away from fossil fuels and towards renewable energy, energy storage has become more important. Batteries and chargeable energy sources are needed to capture excess energy produced; this excess energy can be used when the wind isn't turning the turbine or when the sun isn't shining on the solar panel. In regions where changing seasons bring different sun and wind patterns like here in New England, relying on these methods without a dependable energy storage solution is not sustainable. One innovative solution to this problem is PCMs.

PCM cells are heated when energy is harvested, to the point where they undergo a phase change. Then, when energy is needed later, the PCM cells can undergo a phase change again and release latent energy without changing the temperature significantly.

PCM technology has been successfully implemented in many products including bedding technology. This technology works by responding in real time to the temperature of your body; it takes in the heat produced by your body to induce a physical change in the PCM as opposed to increasing the temperature in the bedding system. Other applications like solar energy storage in addition to optical disk data storage use the same basic principles to occur, interacting with the environment to store energy through phase changes.

However, although this technology is very promising, there are many shortcomings that still need to be worked out for the large scale application of PCMs in energy storage. These shortcomings include the small temperature windows that are required to maintain, the risk of leakage during the liquid phase, cost of materials, and material compatibility. As technology advances, we may soon be seeing more PCMs in our daily lives. Whether it's in our winter jackets or in electronics, this promising material is at the forefront of thermal science.

> "Research into phase-change materials (PCMs) has opened a new door in thermoregulation."

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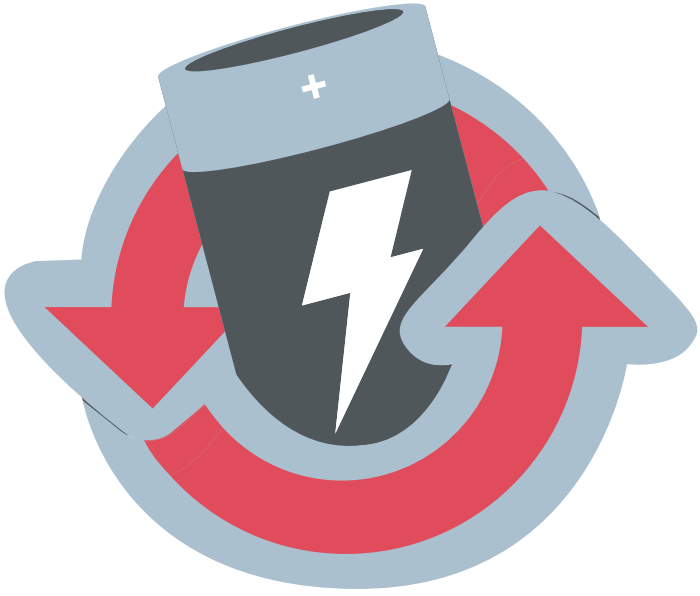

PHOTO BY WIKIMEDIA COMMONS

FEEL THE BURN

HOW INSIGHTS INTO *BURNING* HAVE BETTER *SHAPED* OUR UNDERSTANDING OF *PAIN*

BY THEODORE FISHER, BEHAVIORAL NEUROSCIENCE, 2020

Think back to the last time you burned yourself. Chances are you were cooking, touching up a hairstyle, or getting the wrinkles out of that one shirt that never washes well. Ever since we were young and accidentally touched the stove, it has been a constant struggle to avoid heat-related injuries. Now think about the last spicy thing you ate. The food may or may not have been hot, but still, you feel that same burning sensation.

All types of pain have a complex neurological basis. When the body encounters what it deems to be a harmful stimulus, a sensory response known as nociception occurs that serves to give the body feedback and protection. Specialized receptors on sensory nerve endings, or nociceptors, are activated by stimuli. These neurons then transmit signals to the spinal cord which provides further information to the brain or back to skeletal muscles. In the brain, these signals cause a flood of neurotransmitters, or chemical messengers that can cause systemic behavioral and memory changes. In fact, this is really what causes you to act with caution as well as perceive pain shortly after you are hurt. In some cases, when this danger bypasses the brain through the spinal cord and goes straight to the skeletal muscle, we get a reflex reaction that serves to protect us. These reactions are quick and unavoidable, ready to protect you from further injury.

> "When the body encounters what it deems to be a harmful stimulus, a sensory response known as nociception occurs that serves to give the body feedback and protection."

Unlike any other sensation, burning pain is in a class of its own. Unique neurological feedback mechanisms are what set it apart from aching, tender, sharp, or stabbing pain. Only recently, David Julius, a professor at University of California, San Francisco, uncovered the true underpinnings of burning sensation. Through the careful use of the capsaicin molecule, the spicy component found in chili peppers, Julius was able to discover a new class of nociceptors. His research points to the utility of the TRPV1 nociceptor. By genetically modifying mice to lack this receptor, Julius and his researchers found something incredible. The mice showed an extreme reduction in heat sensitivity and licked their paws much less, a reflex behavior associated with pain sensation.

This family of channels sits right on the membranes of sensory neurons, which can be activated and cause electrical signaling extremely quickly. Julius discovered that not only are these nociceptors chemically activated but also are very sensitive to thermal energy. This alone may give some explanation as to why capsaicin and heat give us similar burning perceptions.

> "In many medical conditions, burning pain contributes to a large decrease in the quality of life."

This information has exciting clinical implications. In many medical conditions, burning pain contributes to a large decrease in the quality of life. Sciatica, arthritis, and multiple sclerosis are some very serious conditions characterized by burning symptoms. Even topical infections such as sores and frostbite involve similar sensations. Because many current pain-killing methods fail to target burning pain specifically, researchers are working to engineer drugs that downregulate TRPV1 signaling. Having both heat and chemical sensitivity, the sheer utility of these nociceptors makes them a likely target for therapeutics. Targeting a specific chemical that interacts with TRPV1 could reduce its output and further signaling to the spinal cord and brain. Through better understanding the mechanisms at play when we feel pain that may in fact be helpful to us, we look to the future for better ways to treat the pain that may hurt us.

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DESIGN BY YECHAN YANG, BIOLOGY AND PSYCHOLOGY, 2021
PHOTO BY SHUTTERSTOCK

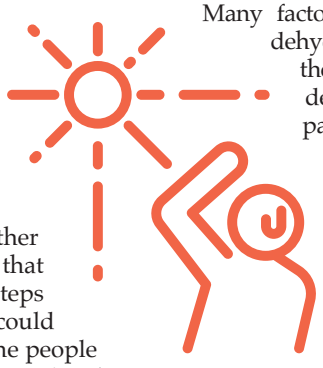
How heat stroke strikes

BY DHRITI AIYLAM, BEHAVIORAL NEUROSCIENCE, 2023

DESIGN BY KRISTI BUI, COMPUTER SCIENCE, 2021

Many of us love to play outdoor sports during the summer. But we hardly think of the dangers -- or if we do, we underestimate them. Symptoms like headaches and cramping are often ignored, believed to be normal consequences of being in the heat too long. But these could be the warning signs of a dangerous illness: heat stroke.

Heat stroke is not a type of stroke, but a type of hyperthermia, a condition in which the body temperature rises to 105 degrees Fahrenheit or higher. Our bodies are normally good at regulating temperature. When our body temperature is too hot (due to any of several reasons, including the environment or our own metabolic processes), there are several mechanisms to cool it down -- most importantly, sweating. But in extreme heat and humidity, the body may not be able to sweat, causing its temperature to rise to dangerous levels.



The first symptoms of heat stroke are relatively benign, and therefore often overlooked. These include headache, nausea, vomiting, muscle and abdominal cramps, dizziness, fatigue, and either heavy sweat or a lack of sweat. It is imperative that during this heat exhaustion stage, a person takes steps to lower their body temperature, or the condition could exacerbate and become heat stroke. However, some people can develop more severe heat stroke symptoms immediately without exhibiting symptoms of heat exhaustion.

If heat stroke is allowed to progress, the victim can suffer neurological changes, which manifest in odd behavior, delusions, hallucinations, and seizures. This happens when proteins and membranes around the brain are destroyed and malfunction. These effects can reach deeper, too; heart muscle cells and blood vessels can break down, and organs can be damaged. For example, in extreme heat, rhabdomyolysis (muscle breakdown) can occur, and the by-products can appear in the bloodstream and damage the kidneys. Delaying treatment can lead to kidney and liver damage, congestive heart failure, coma, and even death.

Many factors increase the likelihood of heat stroke, including dehydration, heavy clothing, being overweight (which causes the body to generate more heat), sleep deprivation (which decreases the rate of sweating), having heat stroke in the past, and using certain medications or illicit drugs.

However, heat stroke is preventable. When the temperature is hot outside, you should remember to stay hydrated with water and sports drinks, wear loose clothing, take frequent breaks if active, and try to avoid being outside during the hottest hours of the day. If you recognize symptoms of heat stroke, you can take preventive measures to keep yourself and others safe in the heat.

Light levels, heavy temperatures

BY ANUSHKA BISWAS,
CELL AND MOLECULAR BIOLOGY, 2023

Close your eyes. Envision a dark and cloudy morning. You're not quite sure what time of day it is, and no one touched the thermostat, but for some nearly inexplicable reason, you feel colder.

Nearly.

In September, the Ecole Polytechnique Fédérale de Lausanne (EPFL), a research institute specializing in natural sciences and engineering, developed a study shedding light on the influence of daylight levels in a room on perceived thermal comfort. It was found that there is a direct relationship between the level of surrounding environmental sunlight and how well participants in the study were able to tolerate heat.

Lead author Giorgia Chinazzo recruited 84 young men and women between the ages of 18 to 25 to fulfill a simple request: spend three hours in a room. Although the task was simple, the results harbored significant implications for the field of psychology. The rooms utilized for the study were one of three temperatures—19°C, 23°C, or 27°C—and daylight levels—low, medium, or high. Color-neutral filters were also randomly positioned to regulate illuminance. After observing the measurements taken continuously of the participants' body temperatures, the conclusions were astounding.

Results indicated that participants in the room set at 19°C felt more comfortable when the chamber was filled with light as opposed to minimal daylight. Unexpectedly, those situated in the 27°C room found themselves to feel cooler despite the room being flooded with daylight—not when light levels were at a low. Everyone's body temperatures remained constant throughout the experiment but their ability to accurately perceive temperature had not.

What might be causing these distorted perceptions? Before entering the study, participants were unaware of the researchers' intended purpose to preserve the sanctity of the results. The effect of daylight is purely psychological.

A pre-existing thermal perception model attempts to explain this shining phenomenon. This model attests that perceived comfort is based on a set of ideal values. As the range of values begins to deviate from the ideal, people tend to report impressions of decreasing comfort. In Chinazzo's study, when the amount of daylight present subconsciously contradicted the expected level of light associated with each level of temperature—whether it be too high or too low—the thermal perception and comfort factors of participants became distorted.

Moving forward, major businesses would benefit from carefully calculating light and temperature preferences to construct a comfortable, productive working environment. Until then, the next time you find it to be just a little too warm, close your eyes.

Scientific Reports (2019). DOI: 10.1038/s41598-019-48963-y

PHOTOS BY SHUTTERSTOCK

HOW HYPOTHERMIA CAN HEAL

BY KRISTINA KLOSOWSKI,
BEHAVIORAL NEUROSCIENCE, 2021

Have you ever heard the saying, "you're not dead until you're warm and dead"? This is because short periods of hypothermia can slow metabolic processes down to the point where the brain requires a reduced level of oxygen.

Hypothermia is a condition in which your body loses heat faster than it can be produced. Generally, you are considered to be hypothermic if your body temperature falls below 95 degrees Fahrenheit (normal body temperature in humans is 98.6 degrees Fahrenheit). While the process is not entirely understood, this is thought to be why you may have heard amazing stories of people surviving after having fallen under the ice for prolonged periods of time, and recovering with relatively minimal brain damage.

While prolonged hypothermia will certainly result in injury and death, short periods of mild hypothermia can actually be therapeutic. The beginning of therapeutic hypothermia (also called targeted temperature management) actually traces back thousands of years, but its uses in modern medicine have been developed mostly throughout the 20th and into the 21st century. Today, it is most widely used in the care of cardiac arrest patients to improve neurological outcomes.

Several different types of neurological deficits occur after cardiac arrest. One is known as hypoxic injury, which is caused by lack of oxygen. Lack of oxygen disrupts several cellular processes and will eventually lead to apoptosis, or programmed cell death (also referred to as cellular suicide). Unfortunately, when apoptosis occurs and a cell ruptures, the contents of the cell leak out and can cause more damage and can trigger an inflammatory response. This is particularly detrimental in the brain, where even a minor swelling response can cause substantial brain damage. Hypothermia combats this by counteracting the excitatory response that leads to cell death. It also reduces the severity of the inflammatory response of the immune system in the brain.

Recently, the idea of selectively cooling the brain has taken hold in expanding treatment options for other severe conditions. Selective brain cooling in traumatic brain injury (TBI) is being studied at Vivonics, Inc., a small medical device company whose mission is to develop innovative technologies to improve human health and performance. Vivonics has received grants from the Department of Defense (DoD) to research and develop products that are intended for use in the field. Since DoD personnel are at a higher risk for traumatic brain injury due to the nature of their job, a need was identified for a technology that could mitigate the secondary effects of TBI, and was designed with field use in mind.

Meet ICEPICC. Short for Intranasal Cooler for Encephalopathy Prevention in Combat Casualty, ICEPICC is a hand-held intranasal cooling system; an easy-to-operate technology that marries an expertise in traumatic brain injury with the ever-growing need for better combat casualty care. It has been shown to provide effective cooling through a forced cold-air convection system, which delivers cooled air to the brain via a nasal cannula. By cooling the brain to normothermic—normal body temperatures—or mildly hypothermic temperatures, the inflammatory response that occurs after a TBI can be quelled. This plays a huge role in reducing the severity of any brain damage that occurs, as well as reducing the risk of mortality.

As Gordan Hisrchman, the CEO, president, and founder of Vivonics explains, "when someone suffers a head injury, there can be both immediate damage to the brain as well as secondary damage that occurs after the initial trauma. Our ICEPICC intranasal cooling system can help minimize the secondary damage if applied promptly after the initial injury, greatly improving outcomes in cases of traumatic brain injury."

Though not yet FDA-approved, ICEPICC is still under development by a skilled team of engineers. This exciting innovation is an example of the evolution of therapeutic hypothermia and its many potential applications in modern medicine.

DESIGN BY YECHAN YANG, BIOLOGY AND PSYCHOLOGY, 2021
PHOTO BY SHUTTERSTOCK

Copycat arson: Accelerating the damage of the California wildfires?

BY LAUREN VOSO, BIOLOGY, 2023
DESIGN BY NICHOLAS BERRY, ENGINEERING, 2024

Coverage on the California wildfires have become a constant in the news. As climate change seems to worsen the likelihood and extremity of wildfires, there has been a corresponding increase in the coverage of wildfire events. From the brutal burning of Paradise to the destruction of parts of natural parks like Yosemite, the public is able to witness in real-time the complete tragedies caused by these wildfire events. The evolution of instant media coverage has its benefits; viewers are able to be educated on these wildfires and are encouraged to help support those affected by them. But an unintended effect of this large-scale media coverage of wildfires has yet to be thoroughly investigated. Is it possible that media coverage might be inspiring individuals to commit "copycat arson"?

Take Freddie Owen Graham. A resident of Missouri, Graham flew to California this September and drove down Calaveras Road in Santa Clara County with a rental car, setting fires as he went. His fires ended up burning 128 acres of land.

Graham isn't the only one with an urge to intentionally start wildfires. Last year, Forrest Gordon Clark was charged with setting fire to Cleveland National Forest, a fire that resulted in burning of over 10,000 acres and 20,000 evacuations. Several others have committed similar crimes, resulting in widespread destruction and disaster for those affected. In fact, despite an overall decline in arson in California since 1985, in the past three years, the number of reported arsons has been on the rise. While it's not certain this increase is associated with the large media coverage of wildfires, it is suspected that many of the arrested arsonists are inspired by what they see on the news.

Mental health is also an important factor to consider when looking at those who are intentionally setting wildfires. Psychologists from University of California, San Francisco have linked several mental health issues with arson, including schizophrenia and depression. Studies have shown that those who set intentional fires are generally more socially isolated than other violent offenders. Arson is also associated with substance abuse, often in connection with other mental health issues. For more extreme cases, individuals may be diagnosed with pyromania, in which the person has an impulsive obsession to start fires.

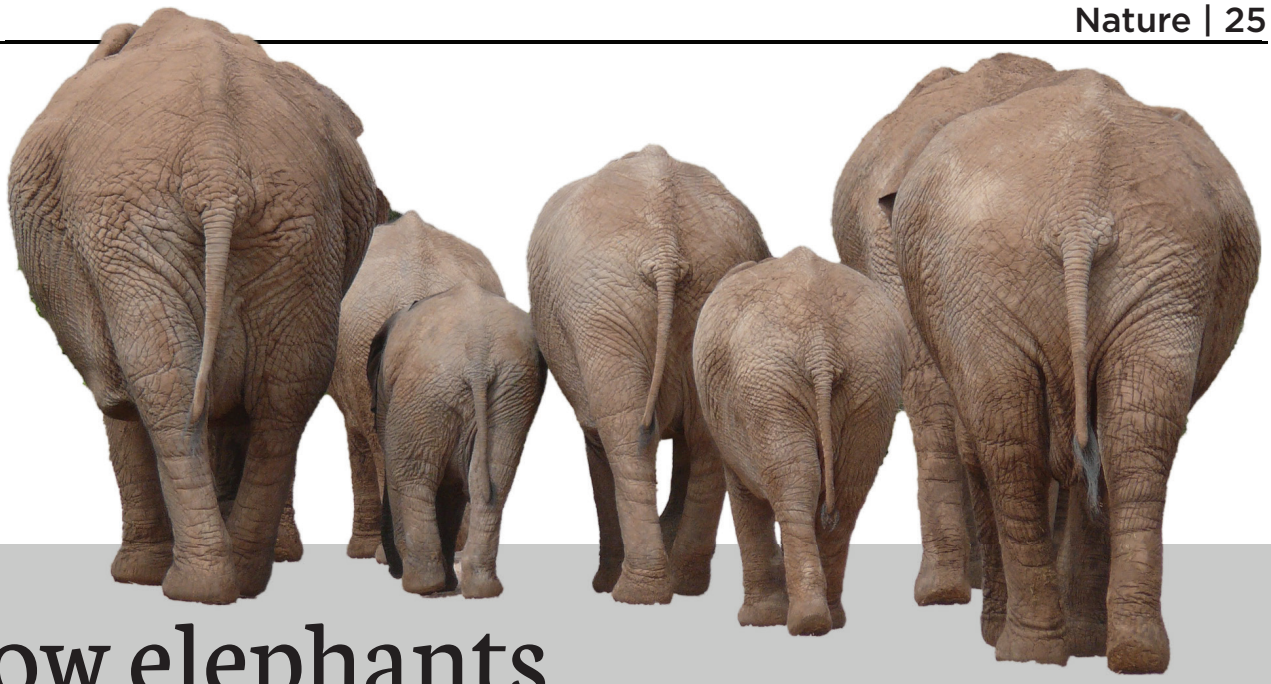
The idea of a copycat crime is an interesting phenomenon, which may be at play here with the arsonists in California. Usually, we associate copycat crimes with copycat killers: those who are inspired by a serial killer in the news and decide to kill others in a similar way. Copycat crimes are also often inspired by other forms of media, like crimes seen in films or on TV. Experts on copycat crimes claim that if a particular crime comes in waves, it is often caused by a cycle of imitation. It is also believed that if a type of crime gets excessive media attention, the risk of imitation increases. This excessive media coverage can inspire "edge-sitters," people in between normal and criminal behavior, to take action corresponding with their criminal side. Because of the widespread news coverage of wildfires, it's likely that a cycle of copycat arson has been evoked.

> "From the brutal burning of Paradise to the destruction of parts of natural parks like Yosemite..."

Human causes of wildfires, whether they be intentional or accidental, need to be eliminated as the west coast faces increased damage from these unnatural wildfires. The instant media coverage may be accelerating these crimes, as images of wildfire destruction are so accessible to the public and may inspire individuals to recreate the scenes they view so vividly. Although it may be hard to change the format of today's media, we should be more aware of the impact of our news reporting and how it may be provoking those on the edge of crime to take action.

Journal of the American Academy of Psychiatry and the Law (2012). 40 (3) 355-365

PHOTOS BY JONAH LEVINE



How elephants keep their cool

BY PAULA HORNSTEIN, BIOCHEMISTRY, 2020
DESIGN BY HEATHER WELCH, ENVIRONMENTAL SCIENCE, 2020

The African elephant has the largest ears of any animal on the planet. This superlative, however, has utility beyond just aesthetics. Unlike humans, elephants cannot depend on sweat to cool them down, as their only sweat glands are between their toes. An elephant's flapping ears act as fans to create a breeze and contain blood vessels that dilate to increase blood flow and cooling. Their ears can help lower an elephant's body temperature by 5 degrees Fahrenheit.

The African elephant's ability to stay cool in the hot sub-saharan sun had long been attributed to these large ears. But these are not the only factors that help them to keep cool in temperatures that rarely drop below 77 degrees Fahrenheit. Multiple studies have shown that the process of keeping an elephant cool is much more complicated than previously believed.

> "Unlike humans, elephants cannot depend on sweat to cool them down, as their only sweat glands are between their toes."

One contributing factor is the elephant's long, sparse hair all over its body. Hairs conduct heat away from the body, and the sparsity of the hairs is necessary to allow for the release of heat from the skin. Too much hair would be insulating and cause heat to be retained instead of released. In a light breeze, these hairs can allow for an increase in heat loss of up to 23 percent, based on models from Princeton University researchers.

> "The most recent discovery regarding elephant temperature homeostasis is the significance of wrinkles."

Another key attribute is the permeable character of elephant skin. A 2013 study published in the *Journal of Experimental Biology* found that this permeability allows for increased evaporation without the barriers that animals with generally impermeable skin (like humans) have. This mechanism of cooling is similar to human sweating: As high-energy molecules from in or on the skin evaporate, heat is lost and the body is cooled.

The most recent discovery regarding elephant temperature homeostasis is the significance of wrinkles. Their wrinkles are beneficial in two ways: They provide increased surface area of the skin, allowing for greater heat loss, and form crevices. These crevices can hold mud, water, and clay from a mud bath or splash in the watering hole, retaining the moisture from these materials for further evaporation. The process of how these wrinkles form is still not well-understood, as a 2018 article published in *Nature Communications* could not fully address this enigma. Further knowledge of the evolution of these wrinkles will help us to better comprehend just how the evolution of elephants allowed them to thrive in their environment.

Nature Communications (2018). DOI: 10.1038/s41467-018-06257-3
Journal of Experimental Biology (2013). DOI: 10.1242/jeb.080218
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PHOTOS BY PIXABAY

As temperatures rise, so do female sea turtles

BY MAYA HOMAN, JOURNALISM MAJOR, 2023

DESIGN BY KYLA VIGDOR, DESIGN, 2021

American news sources dubbed 2018 the "Year of the Woman." In 2019, certain members of the animal kingdom are following suit, albeit in an unexpected way: on beaches across the globe where sea turtles lay their eggs, the hatchlings are skewing almost entirely female.

Sea turtle eggs must incubate in the sand for anywhere from 45 to 80 days, depending on the species. Unlike in humans, in which a baby's gender is determined by the 23rd chromosome in a sperm cell, the environment plays a pivotal role in determining the gender of reptiles and certain species of fish. Eggs that incubate at roughly 84˚F have an even mix of genders when the baby sea turtles hatch, while temperatures below 81.9˚F skew almost entirely male, and temperatures above 87.8˚F skew almost entirely female. Now, recent studies from Cape Verde, Australia, California, and Florida are reporting that recent hatchlings are dominated by female turtles. The culprit? Climate change.

The hottest year in recorded history was 2016, and 18 of the 19 hottest years have been documented in the 21st century. Ocean ecosystems in particular are very sensitive to temperature changes. The extreme ratio of female to male turtles could have a disastrous effect on the sea turtle population. Females make up 87 percent of the current adult sea turtle population, and the ratios are only growing more extreme, with some studies counting 116 females for every one male hatchling. Because sea turtles do not typically mate until age 35 to 40, the effects of this particular phenomenon may not be felt for years.

However, there are conservation groups dedicated to tackling the issue. In Australia, the Raine Island Recovery Project has been studying regional trends among Australia's green turtles and working to protect turtles who come ashore to lay eggs. Researchers in Cape Verde have gone a step further by retrieving eggs laid by sea turtles and relocating them. Separating the eggs into smaller clusters helps ensure that they incubate at lower temperatures and scientists have also tried installing sprinkler systems to artificially regulate the temperature. Marine biologists hope that human intervention will be able to partially restore the balance.

PHOTO BY SHUTTERSTOCK

Current Biology, (2018); DOI: 10.1016/j.cub.2017.11.057
MEPS (2019); DOI: 10.3354/meps1296

Don't sweat it: The truth behind perspiration

BY WILLIAM BONAVENTURA, APPLIED PHYSICS, 2021

DESIGN BY ANANYA DHANDAPANI, UNDECIDED, 2023

A small bead of sweat slowly slithers down your forehead. The clothes you have just changed into are already soaked. You stare up at the sun, loathing the great glowing orb, as you realize how disgusting you already smell. On the surface, perspiration is a grotesque act that soaks clothing and exudes an odor repulsive to the world. Yet surprisingly, sweat is not actually to blame for how awfully we reek. In fact, not only is this excreted salty liquid actually innocent of such a wretched scent, it also provides us with a number of health benefits. Sweating serves as the body's natural cooling system, preventing it from rising to dangerous temperatures and suffering symptoms such as heat stroke.

Let us take a microscopic look at the actual culprit of the putrid odor. Sweat, in reality, is primarily water containing meager amounts of dissolved minerals, primarily sodium and potassium (i.e. table salt). It is effectively a colorless, odorless liquid. What is the origin behind reeking so badly, you might ask? According to MedicalNewsToday, an online outlet for medical media, the unsatisfactory scent is actually due to the presence of various strains of bacteria residing in said sweat. The degradation of salt into acids is the process that in turn releases the order. Hence, the interaction between the unicellular organisms and our sweat is the main source of the stench.

> "However, not only is this excreted salty liquid actually innocent of a such a wretched scent, it also provides us with a number of health benefits."

Not only is bacteria, rather than sweat itself, the primary body odor culprit, the act of sweating is an essential step in our regulatory system process for maintaining a homeostatic balance. In response to a rising, potentially dangerous body temperature, the body triggers sweat gland activity, releasing the salty discharge onto our skin. In the evaporation process that follows, liquid water in the sweat transitions into water vapor, effectively carrying a bit of body heat away with it. As all of the moisture hot enough to evaporate leaves our body, only the cooler liquid water remains, effectively chilling our quickly warming body. In addition to keeping us cool, sweating has also been credited with boosting energy, improving mood, and detoxifying our bodies of various heavy metals.

While our first instinct may be to curse the vile effects of sweat, we instead actually owe the process a great deal of gratitude. Without it, surviving a marathon in the blistering heat would instead involve excessive panting. Be thankful for our sweat glands!

From a mountain of fire to a mosaic of life

BY RYAN BRADY, CHEMICAL ENGINEERING & BIOCHEMISTRY, 2022

DESIGN BY KAI GRAVEL-PUCILLO, ENVIRONMENTAL SCIENCE, 2021

As the sun rose on May 18, 1980 in Skamania County, Washington, all appeared to be normal; however, this would all change rapidly. At 8:32 AM, an earthquake caused a massive landslide leading to the eruption of Mount St. Helens. The eruption sent lava and rock down the northern face of the volcano, destroying everything in its path. It also triggered the release of a hot gaseous cloud, instantly searing everything it touched. The finale of the eruption was the massive plume of ash that shot into the sky and coated the surrounding area. Fifty-seven people died from the eruption, and it caused $1.1 billion in damages. Beyond the economic and human impact, the environmental impact was unprecedented. Virtually everything that came in contact with the eruption was annihilated. Over time, however, the environment has been rebuilding, first with grasses and small bushes and eventually blooming back into a luscious forest. This process of recovery is known as succession.

Succession is the ecological process in which ecosystems change over time. The process can take anywhere from decades to millions of years. After most disruptions, one of two types of succession occur: primary or secondary. In primary succession no soil is present, such as in the areas of newly formed rock. Secondary succession occurs when the soil remains intact and is a significantly faster process. This is the type of succession that would occur after an event such as a forest fire.

With an event as traumatic and multifaceted as the eruption of Mt. Saint Helens, the process of succession is a very complex and nonlinear one. Because areas were impacted unequally by the eruption, different areas have recovered at different rates. The nearby lake, Spirit Lake, has recovered the fastest but may never fully return to its original state. The lake was initially a deep lake that was pristine as a result of the runoff from the mountain; however, when the eruption occurred, the flow ended up in the bottom in the lake—creating a warm, shallow, and oxygen-deprived environment. Initially, a small number of anaerobic bacteria began growing in the lake. Over time, the debris has cleared from the surface, increasing the light transmittance and allowing the redevelopment of plant and animal species. Additionally, the illegal introduction of rainbow trout in 1993 served as an interesting ecological event, as the fish have exhibited shorter life cycles but grow larger. Scientists attribute this to denser vegetation that has developed without any natural predators, which allow the trout's prey to thrive.

One of the most unique aspects of the volcanic eruption was how some species were able to survive and repopulate quickly while others were completely wiped out. These successful species are known as "biological legacies." Among the first organisms to reemerge were fungi. Certain species of fungi have adapted to grow after forest fires but had responded in a similar manner to the eruption. Because of the relatively small area of impact of the disruption in comparison to a forest fire or similar disturbance, many early plant colonizers were blown into the area from the surrounding forest. The first animals that emerged were mice and moles. The moles served a unique role because their burrowing mixed the soil and the volcanic ash making it much more hospitable for new plant growth. More recently, trees that were present before the eruption have begun regrowing in the area. Currently, the canopy ranges from 15 to 25 feet tall—composed of mountain hemlocks and Pacific silver firs. Despite this progress, the area is still decades away from resembling the pre-eruption ecosystem.

The most intriguing aspect of Mount St. Helens is its never-ending cycle of succession. Since different areas received different impacts from the 1980 eruption, they represent a mosaic of recovery statuses—some of which have fully recovered, whereas others are still years away from looking remotely like the original ecosystem. Yet at the same time, the active volcano looms large over the area with predictions for another eruption well within the lifetime of the developing trees. In the meantime, smaller disturbances like avalanches and erosion have reset the ecological clocks of patches. Overall, the succession following the eruption of Mount St. Helens has presented a unique opportunity to study a variety of disturbances as a result of one massive event.

PHOTOS BY SHUTTERSTOCK AND SAMUEL KLEIN, BIOLOGY, 2022

Falling for autumn colors

Why and how vibrant fall leaf shades are produced

BY CLAIRE BOHLIG,
MECHANICAL ENGINEERING, 2023

Walking through Centennial Common on a bright autumn day, it is impossible to ignore the students in cozy sweaters taking photos of trees displaying a mosaic of reds, oranges, and yellows as the season changes.

These vivid colors are caused by the presence of three different types of pigments in aging leaves: chlorophylls, carotenoids, and anthocyanins. Chlorophylls, of type A and B, are the green pigments of photosynthesis and are produced in the chloroplasts of leaf cells. Since photosynthesis occurs in healthy leaves to provide the tree with food, leaves are green before they age. Once the leaf begins to die, it breaks down these pigments and reabsorbs the nutrients. Carotenoids are left over once the leaves lose chlorophyll and scatter yellow wavelengths. Anthocyanins are water-soluble pigments produced during metabolic processes in the leaf and scatter red wavelengths that lend color to red fruits and autumn leaves.

Leaves change color as the relative amounts of the pigments present in the leaf change. Chlorophyll decreases right before the leaf falls in autumn, leaving behind any carotenoids and anthocyanins that had been produced in the life span. But unlike carotenoids, anthocyanins are produced right before the leaf dies, so there is a short period of time where anthocyanins are more present than chlorophyll, and the leaf turns brilliant red.

The mixing of pigments also occurs. When both anthocyanins and chlorophyll are present, the leaves are brown, and carotenoids and anthocyanins create bright orange. Even levels of anthocyanins within the same leaf tend to differ, resulting in ombre and spotted red leaves.

Leaves fall as the tree shuts down for winter, labeling leaves as nonessentials as it goes into the cold winter months. And as much as it pleases humans to see picturesque colors in the fall, trees must have a biological reason to paint landscapes in yellow, orange, and red.

It used to be universally accepted that color change was solely a result of chlorophyll leaving, and therefore the pigments had no biological function as colorants. However, in the 1990s it was suggested that color change must have some sort of evolutionary function for a tree; the puzzle is figuring out what.

There are two branches of science that try and answer this hypothesis. The first is physical explanations for vibrant leaf colors. One physiological explanation is that color change, and the production of anthocyanin, shields photosynthetic tissue in leaves from harsh light and cold temperatures in autumn. This allows the leaf to produce nutrients later in the season than if the chloroplasts (where nutrient production takes place) were exposed. Also, anthocyanins are strong antioxidants which would slow aging of the leaves and extend the life of the tree.

The second branch is that color change occurs for a biological reason. A change in leaf color could signal the tree as toxic to bugs that lay eggs on or animals that eat the trees' leaves. Mainly this theory applies to yellow leaves and has been observed in birch trees. Trees that turned a more vibrant and prevalent yellow had fewer eggs and less consumption than trees that didn't. An alternate explanation is that colorful leaves will signal for fruit eating birds to find, eat, and spread the berries or nuts of the tree. Most deciduous trees no longer bear fruit, but color change may be a residual biological response from when trees once did.

A few things affect if you can get that perfect fall color Instagram shot. First, summer drought stresses out trees and causes them to kill off leaves before color change begins. Second, anthocyanins (reds) require sunlight for production and are enhanced by cold, sunny days; crisp weather will ensure vivid red and orange foliage. Finally, rainy and windy weather during peak autumn days prematurely knocks leaves down, shortening the color display period.

With summers growing hotter and drier with climate change, it will become more and more rare to see vivid displays of color in autumn. If you're lucky enough to live in Boston, or anywhere else with a fiery autumn, be sure to soak up the colors while you can.

Plant Physiology (2003). DOI: 10.1104/pp.103.027631

DESIGN BY KATIE GREEN, BIOENGINEERING, 2022

PHOTOS BY BRIANNA WATTS, BIOENGINEERING, 2023, SAMUEL KLEIN, BIOLOGY, 2022, AND GUS MUELLER, BIOENGINEERING, 2022

FIRE'S FORCE FOR GOOD

BY SANJANA MISHRA, COMPUTER SCIENCE, 2023

DESIGN BY KYLA VIGDOR, DESIGN, 2021

Growing up in California, with Smokey Bear grinning down from every billboard remotely near the "wilderness," I was always against the idea of fire. To me, fires destroyed lives and homes, and caused me to experience respiratory difficulties. The only benefit of a fire was that school was cancelled for a day due to poor air quality, but that came at the cost of thousands of displaced families. Only after moving to Boston do I understand the value of fire as an important component of a healthy environment.

As footage of fires tearing through California plays on televisions across the nation, it can be easy to vilify this force of nature. After all, fires displace hundreds of people each year, and destroy homes and businesses. In fact, the United States Forest Service estimates that around 73,000 wildfires cumulatively destroy about seven million acres of land every year. This number may only increase; climate change makes these blazes more frequent due to higher temperatures and drier weather patterns. With populations expanding, these fires pose a dangerous threat in terms of long-term health, as well as short-term upheaval of lifestyle. Each time there is a threat of a fire, officials encourage residents to evacuate, and in some cases, residents do not have a home upon their return. Additionally, the ash and debris in the air can lead to respiratory issues that can later cause serious health problems. But are forest fires only bad? The short answer is no—fires clear the underbrush for new growth, and are a natural, renewing force of nature. The long answer is a little more nuanced.

Created in 1911, the U.S. Forest Service almost immediately implemented a policy to stamp out forest fires as quickly as possible. This policy was put into action after a fire blazed through Idaho and Montana, killing almost 100 people, and destroying three million acres in only two days. However, in the 1990s, the U.S. Forest Service adopted a more "natural" policy, initiating a program to clear brush and dense forests in order to prevent uncontrolled forest fires. Underbrush, and dry timber from dying trees, fuels uncontrolled fires, but when such fires are prevented, the brush becomes thicker, and dry timber accumulates. By removing the fuel from the forests, the U.S. Forest Service reduces the likelihood of another uncontrollable forest fire. Through this new policy, the U.S. Forest Service extinguishes forest fires close to communities, but also recognizes the importance of forest fires in maintaining a healthy ecosystem.

The U.S. Forest Service now utilizes the technique of controlled, or prescribed burns. Essentially, firefighters set a certain section of a forest on fire, and watch the site to ensure they maintain continual control. By using this method, they can keep these fires away from communities, while maintaining the cycle of undergrowth renewal of a healthy ecosystem. A 40-year-long study by the Tall Timbers Research Station, in Tallahassee, Florida, proved the importance of forest fires to sustaining habitats and biodiversity. During the study, a forest of around 57 acres experienced no fire damage. Over 40 years, plant diversity decreased by 90%, and this "fire-drought" led to the contained extinction of a local bird species, the red-cockaded woodpeckers. These woodpeckers need healthy trees in order to survive, but new growth of vegetation and trees are restricted without the necessary, fiery revitalization of the habitat.

While fires can be good for clearing underbrush and revitalizing ecosystems, there are some concerns about the impact on communities as a whole. Along with respiratory issues experienced by people living close to these prescribed burning areas, there is also the risk that a prescribed burn could go wrong, and endanger entire communities.

Fires are not solely bad nor good. When left unchecked near communities, or started recklessly, there can be dangerous consequences. However, the positive outcomes of forest fires—the stimulation of growth in ecosystems, preservation of healthy habitats, and the prevention of larger, deadlier forest fires—show us that nature requires some destruction for the greater good. It can be easy to paint fire as black or white, good or bad, but it is important to remember that fire has the power to damage, create, and conserve.

PHOTO BY SHUTTERSTOCK

THE BEST WAY TO LOSE WEIGHT? USE FAT CELLS AND COLD TEMPERATURES!

BY THERESA CHUNG, HEALTH SCIENCE, 2023

DESIGN BY ANANYA DHANDAPANI, UNDECIDED, 2023

Fat gets a pretty bad rep. It's typically assumed that fat is bad because it makes you gain weight, so people should do their best to have less of it. But it turns out that there are fat cells that can actually help people lose weight and possibly combat metabolic diseases such as diabetes. Originally it was believed that brown and beige adipose cells—tissue used for the storage of fat—only served a purpose in producing heat, but now it seems as though these fat cells can end up being used in order to stimulate weight loss in humans. Studies from the early 2010s have shown that when exposed to cold temperatures, brown and beige adipose cells can increase their energy usage to burn glucose and fat.

In order to study how brown and beige adipose cells are induced by cold temperatures to undergo heat generation, or thermogenesis, researchers Kajimura, Spiegelman, and Seale measured thermogenesis in mice and then applied their findings to humans, as shown in their 2015 *Cell Metabolism* study. In mice, beige adipose tissue and brown adipose tissue (BAT) form prenatally in order to protect newborns from cold environmental temperatures. Exposure to cold temperatures causes the sympathetic nervous system to release the neurotransmitter norepinephrine, which activates the beige and brown adipose cells. Once these adipose cells are activated, the mitochondrial uncoupling protein 1, a protein present in both brown and beige adipose cells, can activate to generate heat.

Beige adipose tissue is directly affected by cold temperatures and reacts through inducing thermogenesis, while brown adipose tissue is indirectly affected, meaning it must first receive a response from the central and sympathetic nervous system. Both brown and beige adipose cells share the ability to utilize thermogenesis, not just in a way that heat is produced to stay warm, but also to use this heat to burn glucose and fat.

> "In addition to maintaining homeostasis, beige adipose tissue has also been found to be more effective against weight loss and metabolic diseases."

In addition to maintaining homeostasis, beige adipose tissue has also been found to be more effective against weight loss and metabolic diseases. Another study by Spiegelman, published in 2013 in *Proceedings of the National Academy of Sciences*, found that when brown and beige fat is removed from a mouse, more fat accumulates and insulin resistance builds up, which leads to an increased risk for weight gain and diabetes. This means that the presence of brown and beige fat is necessary in order for mice, and even humans, to regulate weight.

Adult humans have been found to have a mixture of both brown but mostly beige adipose cells in the supraclavicular region, the area above the collarbone. It also turns out that humans who are slimmer and younger have more BAT in their supraclavicular region than those who are older and larger. Similarly to mice, when humans lack brown and beige adipose tissue, they are more likely to experience weight gain or diabetes. The same study in 2015 by Spiegelman showed that when exposed to the cold, adult humans have also shown increased activity in beige adipose cells. This increased activity represented an increase in the rate of glucose and fat being burned. This means that humans are actually capable of natural weight regulation through brown and beige adipose tissue activity.

Essentially, a human's metabolism could increase by stimulating BAT activity through cold temperatures. This increase in metabolism could help to reduce weight gain and also reduce the risk of diabetes in humans. It seems as though losing weight and lowering the prevalence of diabetes in today's society could be done simply through exposing humans to the cold in order to induce the BAT activity in their bodies.

Proceedings of the National Academy of Sciences (2013). DOI: 10.1073/pnas.1310261110

Cell Metabolism (2015). DOI: 10.1016/j.cmet.2015.09.007

PHOTOS BY SHUTTERSTOCK AND PUBLIC DOMAIN FILES

Capsaicin igniting the trail to extingush lung cancer

Does the chemical in chili peppers have the potential to slow the growth and spread of lung cancer?

BY CAILEY DENONCOURT, BIOENGINEERING, 2022

The burning, eye-watering taste of a chili pepper is an experience only some enjoy. Capsaicin is the active ingredient that makes chili peppers so hot and an extreme irritant in high concentrations. Recently, scientists have noticed an unusually low rate of lung cancer in countries with traditionally spicy food. Thus, capsaicin could be more than a key ingredient in some amazing dishes; in the lab, it is being examined for potential benefits for those with lung cancer.

In very small concentrations, capsaicin has already been used in ointments for pain relief, but its medicinal purposes continue to expand. In particular, the molecule has anti-neoplastic properties in a variety of human cancer cells. This means that it could both inhibit and prevent the development of tumors. Research has indicated capsaisin's potential role in apoptosis (cell death) of cells for non-small-cell lung cancer (NSCLC), T-cell leukemia, prostate cancer, colon cancer, and more. But further, cancer becomes deadly and extremely difficult to treat when it spreads, or metastasizes, to other organs in the body. To fight against this, capsaicin has also been shown to inhibit the cell cycle of cancer cells, thus preventing tumor growth both within the primary organ and in a potential secondary organ.

Although capsaicin has many medicinal benefits, the chemical also comes with some adverse side effects. Patients may experience gastrointestinal irritation, stomach cramps, nausea, skin redness, vomiting, or burning diarrhea, along with other possible symptoms. However, with limited studies in the potential long-term side effects of capsaicin on patient health, there still remains a lot of unknowns. Thus, research on capsaicin-like molecules is being examined for potentially maintaining its anti-neoplastic benefits, while reducing the negative side effects.

At the Experimental Biology meeting in April 2019, Jamie Freidman, a recent PhD graduate in Piyali Dasgupta's lab at Marshall University, reported the investigation into the effects of capsaicin and other capsaicin-like compounds on lung adenocarcinoma, which is a specific form of lung cancer that forms in glands allowing it to easily spread and metastasize. The two derivative molecules of capsaicin Friedman is working with are capsiate and capsiconiate. Both only have minor changes compared to the structure of capsaicin, and hence their bioactivity closely resembles that of capsaicin. In their study, the mouse models that had capsaicin in their diet showed a significant decrease in the metastatic area in the lung, indicating a decrease in the growth of the tumor. When observing the effects of capsiate and capsiconiate through the examination of invasion assays, capsiate successfully showed anti-invasive properties.

More recently, in October 2019, Friedman published a review investigating the effects capsaicinoids, derivatives of capsaicin, have on metastases. One characteristic of tumors is the formation of new blood vessels, called angiogenesis, which causes the tumor to take the oxygen and nutrients from cells that are vital for organ function. A study by Min et al. in 2004 showed how capsaicin suppressed the production of vascular endothelial growth factor, thus preventing the growth of these new blood vessels. Therefore, without the proper nutrients, the tumor is unable to grow and spread. This result was also similarly found in capsaicin derivatives like capsiate.

Another critical step in tumor metastasis is known as the epithelial-to-mesenchymal transition (EMT). In order for the secondary tumor to form, the cells must be able to travel through the body without being deemed a foreign enemy by the immune system. Thus, part of the EMT is the removal of markers that specify the cells to their primary region and replace these membrane markers with mesenchymal markers, which are applicable to a greater range of cell types. In 2013 Yang et. al. found that capsaicin supported the EMT transition, whereas in 2014 Wutka et. al. found that capsaicin did the exact opposite.

The overall effects of capsaicin remain unknown and controversial. For every study supporting the positive effects of capsaicin in slowing the growth and spread of tumors, there is another study demonstrating the reverse. Thus, research continues to examine the question: is capsaicin a key in the treatment of cancer? It's a hot debate.

PLOS ONE (2010). DOI:10.1371/journal.pone.0010243
The FASEB Journal (2019). DOI: 10.1096/fasebj.2019.33.1_supplement.368.1
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DESIGN BY LILLIE HOFFART, ENVIRONMENTAL SCIENCE, 2022
PHOTO BY SELINA BANERJEE, CHEMICAL ENGINEERING, 2022

DEADLY HEAT: How rising temperatures impact low-income urban communities

BY YASMINE MYFTIJA, BIOLOGY, 2021
DESIGN BY KRISTI BUI, COMPUTER SCIENCE, 2021

Picture this: **It's the middle of summer and it's sweltering outside.** You'd think getting out of the sun would be as easy as taking a dip in the pool or turning on the air conditioning until your room cools down. However, in low-income urban neighborhoods, the rapidly increasing summer temperatures can often be inescapable and sometimes even deadly.

A recent study conducted by National Public Radio (NPR) in conjunction with the University of Maryland's Howard Center for Investigative Journalism found that there may be a relationship between income-level and temperatures in metropolitan areas. For example, people living in the poorest neighborhoods of Baltimore, Maryland suffer from the hottest temperatures in the city, measuring at nearly 6 degrees hotter than those of their wealthy counterparts. Other cities within the United States were found to have an even stronger relationship between income and temperature, including Las Vegas, Los Angeles, Oakland, Anchorage, and Portland.

NPR and the University of Maryland collected data of temperatures for each block in major cities in the United States beginning with Baltimore. They also worked with NASA's software and satellite imagery as well as median household income data to study whether a relationship between income level and heat existed, and to what degree. The satellite images helped them determine whether there was a physical reason for this relationship, such as the style of building or greenery. Median temperatures were calculated and used as a basis for comparison. Cities were rated as having anywhere from a weak to strong relationship between income and heat. Poverty rates from the United States Census were also used in the study.

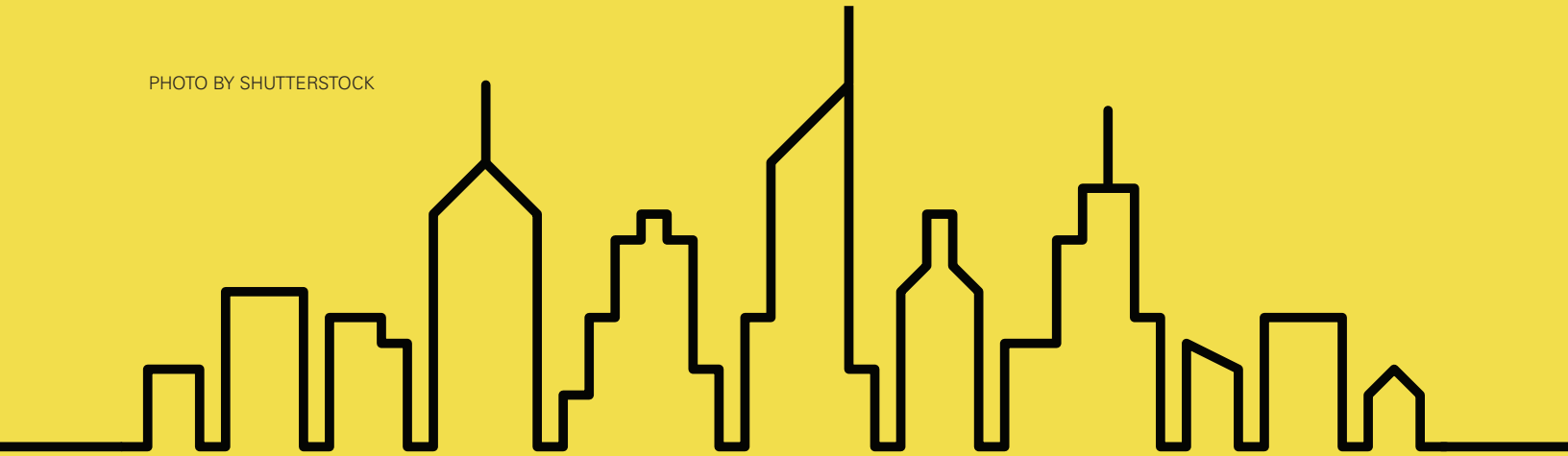
Unfortunately, the blazing heat is only a fraction of the problem. In Baltimore, when temperatures reached a dangerous 103 degrees Fahrenheit, the risk of fatal heat stroke increased dramatically, as did complications with cardiovascular, respiratory, and chronic conditions including asthma and chronic obstructive pulmonary disease (COPD). Although the entire city was affected, residents in its poorest and warmest areas were recorded visiting the hospital and utilizing emergency medical services more often than those in cooler, wealthier areas. Often, the very people who live in Baltimore's hottest neighborhoods can't afford to stay inside and risk missing a day of work. And unsurprisingly, they don't have the same access to healthcare as others.

Residents in these areas also have disproportionate access to ways of cooling down. If individuals can't afford to install air conditioning units in their own home, they have to deal with blistering temperatures without an escape, which can negatively impact their health. The lack of parks with pools in low income areas can make the issue even worse.

NPR attributes the difference in temperature to the presence of trees within American cities. While cement, stone, and black pavement retain heat, trees and green cover help keep temperatures on the cooler side. Low-income urban areas often lack the necessary greenery to help combat rising temperatures. Furthermore, these areas are often close to industrial areas containing factories and highways, which have large tracts of roads and few trees.

Some solutions are being pursued. In Baltimore, "splash parks" where children can play in the water to cool off are being built or organized in the communities that need them most. NPR also suggests that since cities are warmer than the suburbs because of their lack of trees, one solution would be to start planting more trees. Cities have a hard time maintaining a healthy tree canopy that adds shade to the environment and lowers temperatures, and while restoration is underway in some cities, budget deficits hinder these efforts, leaving low income areas disproportionately affected by the often deadly heat once again.

PHOTO BY SHUTTERSTOCK



Opinion:

THE SILENCING OF SCIENCE IN THE AGE OF TRUMP

How climate scientists have lost their power amidst a crisis

BY KRISTEN KILGALLEN, PSYCHOLOGY, 2020

Although President Donald Trump and his administration's rhetoric is harmful in shaping public perception of the seriousness of the climate crisis—tweeting, in one instance, that "Global warming is a total, and very expensive, hoax!", invented by the Chinese to get ahead economically—it has always been comforting to know that government scientists and reports will go through a rigorous research process and peer review to state the facts. However, many avid climate deniers are the supervisors of those who are meant to produce these objective reports, which allows them to declare the policies and procedures of the agencies they head. The Trump administration has found a way to suppress the dissemination of climate science and to bypass it when it comes to decision making and climate policy.

DESIGN BY LILLIE HOFFART, ENVIRONMENTAL SCIENCE, 2022

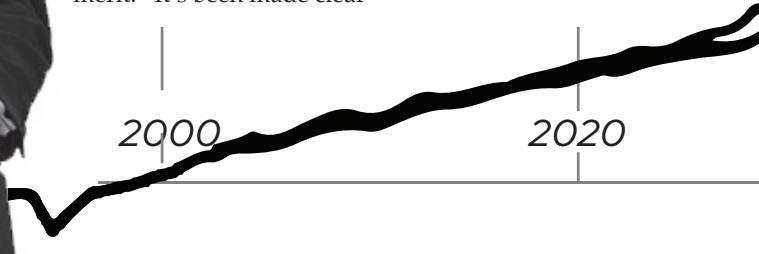
PHOTO BY FLICKR

In many of the United States Department of Agriculture's (USDA) and Environmental Protection Agency's (EPA) most alarming and influential publications, the Trump administration has used a well-known tactic to silence findings: deny, delay and deflect. After the nation's most comprehensive climate assessment was released in 2018, President Trump denied its accuracy, proclaiming to reporters "I don't believe it.". When asked about the report, which indicated that a number of life-altering and dire consequences of climate change were going to occur if no changes were made, officials offered that it was only based on the "worst case scenario" and the next report would be more "balanced." The administration replied to scientists that they "simply disagreed with the paper's conclusions" from a 2018 study from the USDA, which revealed that a carbon rich environment endangered the nutrients in rice, grass and, therefore, the global food supply. The report was written and conducted by Dr. Lewis Ziska, who has conducted research at the USDA for over two decades. Ziska has noted that the number of scientists working with her to study climate stressors has been slashed from 11 to about 4 or 5.

The Trump administration removal of climate data off of government websites, paired with the defying of the longstanding precedent of publicizing and interpreting influential scientific data, has made research findings inaccessible to the public. According to Politico, the Trump Administration has overlooked, dismissed, and evaded the findings of at least 45 studies, and likely more in relation to climate change. In previous years, it has even been reported that officials have not only sanitized reports by the near entire evasion of the words "climate change," climate related words, and even the word "climate" itself, but they have deleted certain findings from press releases. One line famously reported from the Washington Post in 2017 that was deleted, "Global climate change drives sea-level rise, increasing the frequency of coastal flooding," never made it to the public after the report was already delayed from news release for several months.

This top down pressure from government officials not only has direct impacts on the science the public is being exposed to, but has indirect implications for the way scientists self-censor their work. A survey of federal scientist across 16 agencies found that "about one in five reported they had avoided working on climate change or using the phrase "climate change" without explicit orders to do so."

The accounts from dismissed scientists are particularly perturbing, due to the fact that scientists who were doing the work of their agency and serving the American people faced threats, reassignment, and termination on the basis of politics rather than merit. "It's been made clear



> “By the time I left, the morale was the lowest I’d seen in 40 years. Our work had become irrelevant.”

to us that we’re not supposed to use climate change in press releases anymore. They will not be authorized,” one federal researcher said, speaking anonymously for fear of reprisal.“It’s a lot of stuff that definitely filters down, and it affects the reality of people on the ground doing the work when you’re not sure of how I should present this. It’s definitely a huge waste of time.”

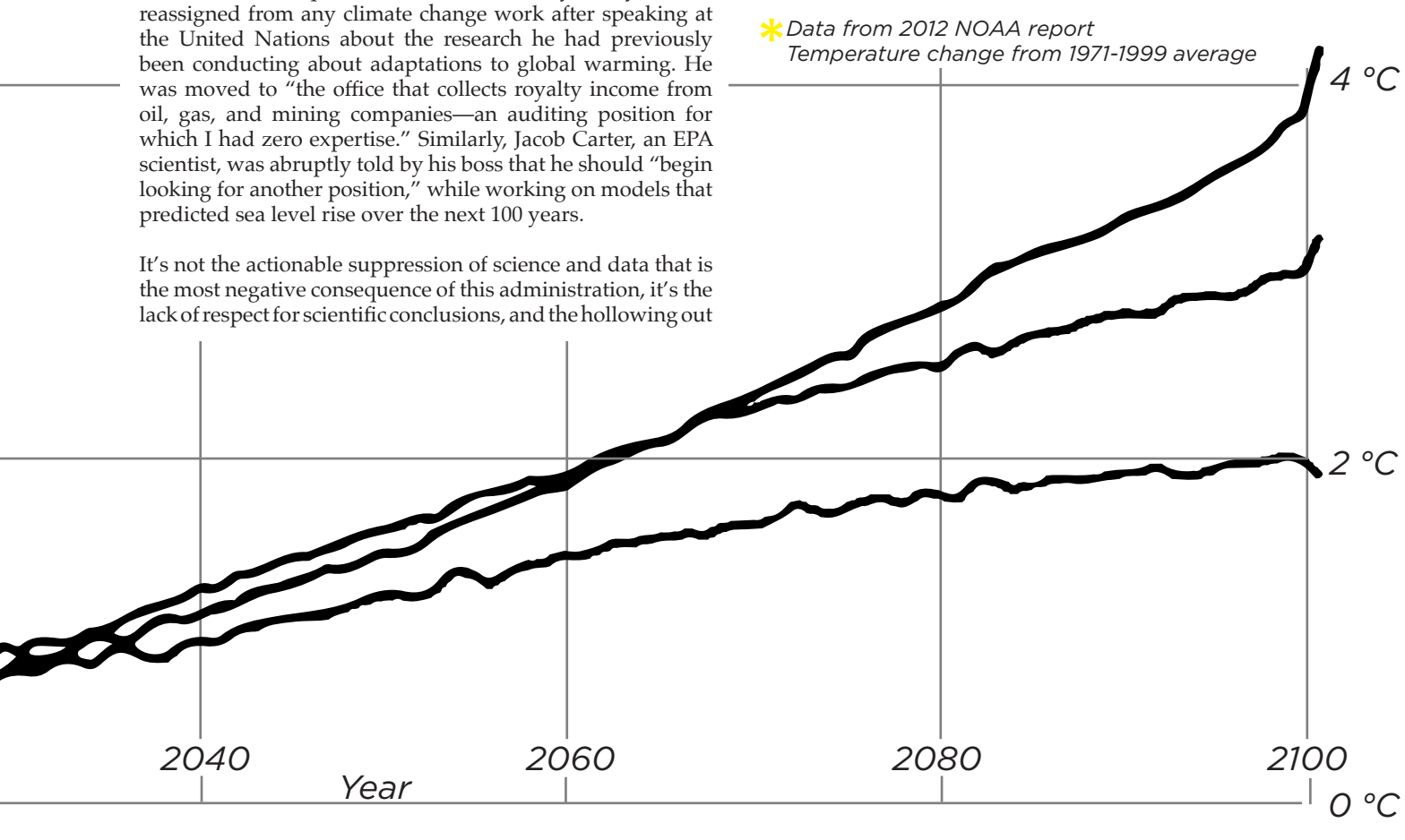
One of the most resonant takes was from National Parks Service scientist Maria Caffrey, whose findings related to climate change’s impact on coastal areas were not publicized. “The excuses varied but became ever more vague, such as ‘we are ever so busy’ or that it would worry people… A superior said they wanted to keep a low profile on climate change for four or maybe eight years while Trump was around… I was told not to attribute changes in public lands to human actions.” Caffrey has been working on the report since 2013, and eventually had her salary lowered to 25,000 a year, and later she was asked to leave the agency. The reason given was budget cuts, but even when she offered to work for free she was still asked to leave, as her work on climate change impacts was no longer needed.

This is an alarming pattern amongst expert scientists in their respective agencies. Joel Clement, the former director of the Interior Department’s Office of Policy Analysis, was reassigned from any climate change work after speaking at the United Nations about the research he had previously been conducting about adaptations to global warming. He was moved to “the office that collects royalty income from oil, gas, and mining companies—an auditing position for which I had zero expertise.” Similarly, Jacob Carter, an EPA scientist, was abruptly told by his boss that he should “begin looking for another position,” while working on models that predicted sea level rise over the next 100 years.

It’s not the actionable suppression of science and data that is the most negative consequence of this administration, it’s the lack of respect for scientific conclusions, and the hollowing out of expertise from scientific agencies that is most concerning for the future of climate change science. Cuts in budget, lack of workers, and change in scientific methodology procedures has made it difficult for scientists to fight back against such attacks on their work. A new climate review panel has been appointed to question the broad scientific consensus and will be headed by William Happer, a physicist who has headed advocacy groups dedicated to debunking climate science and who once, in an interview with CNBC, made the analogy that “The demonization of carbon dioxide is just like the demonization of the poor Jews under Hitler”.

Another shift in methodology was that climate assessments and models that made future predictions past 2040 were no longer allowed, removing the myriad of impacts that were not to take place until later. This is highly alarming because not only does it provide an incomplete and sanitized outlook on the future of the planet, but it removes necessary scientific data that was being harbored and collected to create these future predictions and to come up with solutions on how to prepare.

This calculated side stepping of the most pressing findings in government science agencies is not only problematic for the safety of the human race, but it also is having a big impact on those who have dedicated their lives to doing this work. “By the time I left, the morale was the lowest I’d seen in 40 years. Our work had become irrelevant,” says Jeff Alson, a 62 year senior engineer at the EPA.When the facts and science are no longer welcome, it becomes difficult for scientists to sustain the rigor and energy they once had for their work. Work that keeps all Americans safe. Unfortunately, there has been a dramatic shift in the composition of scientific agencies, board members, and panel members. New policies and personae make burying and silencing the science the norm, rather than the exception.



Why Godzilla is too hot to be real

BY ROXANNE LEE, ENVIRONMENTAL SCIENCE & POLICY, 2019

DESIGN BY KAI GRAVEL-PUCILLO, ENVIRONMENTAL SCIENCE 2021

Sixty-five years ago, Godzilla roared into Japanese theaters and the public consciousness and has barely had a day off since. From 1954 onward, the film character, originally conceived as a metaphor for the horror of nuclear fallout, has starred in dozens of films. The changing monster has grown in size over the years, so that in the 2014 American "Godzilla" film it measures 350 feet tall and weighs 90,000 tons—as much as a large cruise ship.

Could there ever be a chance that something of its ilk could stomp onto our shores?

In a 1986 "Journal of Theoretical Biology" study, physicist J.E.I. Hokkanen calculated a theoretical mass limit for terrestrial animals by studying physics and animal locomotion and anatomy. The formula suggests a general mass limit between 110 and 1100 tons. Hokkanen did not rule out the possibility of unique adaptations allowing a creature to exceed the limit, but it would need unique adaptations the like of which we've never seen before.

A Godzilla of this size would likely struggle just to live. Large animals in real life have adaptations to mitigate the strain on their bodies. Argentinasaurus, a sauropod dinosaur that measured 120-feet long and 100 tons had four thick legs to disperse its weight, as well as a specially adapted respiratory system. The 200-ton blue whale is supported by water's buoyancy. Godzilla can swim, but on land has nothing to support it besides two legs, putting a massive amount of strain on its legs, spine, and hips.

Godzilla could also run into problems with temperature regulation. Mitochondria, the organelles that provide energy for cellular activity, also generate heat. The average human at rest produces 100 watts of power. Just at rest, Godzilla's metabolism would generate 1.4 megawatts, over 1 million times more than a human, and during activity, up to 37 megawatts, as estimated by the magazine Popular Mechanics. If Godzilla's cells did utilize mitochondria, it would require specialized anatomy to vent the excess heat.

Even if the physics conundrum of size could be resolved, there is still the issue of finding a food source that could sustain something of that size and energy output. And none of the above even touches on Godzilla's ability to expel blasts of atomic energy.

Safe to say Godzilla is likely confined to the silver screen. Our cities can rest a bit easier.

Journal of Theoretical Biology (1986). DOI: 10.1016/s0022-5193(86)80167-9

A FUTURE AFTER FOSSIL FUELS

BY EMILY CHEN, BIOCHEMISTRY & DATA SCIENCE, 2023

Fossil fuels have grown to rule our lives, from the use of oil to bond the paint on our walls to the gasoline that powers our cars. For decades, fossil fuel use increased consistently without the government noticing its detrimental effects to the planet. That is, until only about a decade ago, when former Vice-President Al Gore released his documentary film, "An Inconvenient Truth," describing the dramatic toll fossil fuels take on our environment, putting panic in the minds of politicians, environmentalists, and the general population.

The resilience of fossil fuels over the past century surprised scientists, politicians and economists. However, with the growing development of new technologies, the future of energy may not include fossil fuels, but it will include the growing demand for electricity.

For the last century, the primary contributors to electricity have been fossil fuels and nuclear energy. As new technologies rise that can compete with fossil fuels in both efficiency and cost, the use of fossil fuels will decline, leaving nuclear as the primary energy source; however, nuclear cannot be the only contributor to electricity. Its energy can be harnessed into great amounts of electricity, but the cost of storing its waste and social and political acceptability don't allow it to be used as widely as fossil fuels.

The most prominent developing technology is solar power. If any type of energy could wholly replace fossil fuels, this is it. The sun provides an endless power source and it has tremendous potential; about 430 quintillion joules of energy is transferred to the earth from the sun every hour, which is more than the entire world's electricity demand for a year. The potential for this technology seems limitless as new fields of solar energy are being investigated—such as nanotechnology and the use of new materials like graphene—that allow various novel applications to be developed, like being sewn into clothes or placed on cars and buildings.

It's clear this technology won't dominate initially, and there's no guarantee that new developments and modifications to this technology will be successful. However, current studies are promising and the stigma around the use of fossil fuels paired with its increasing price and environmental effect will make fossil fuels undesirable. The future of energy isn't merely solar power or nuclear power; it's a combination of the two. Both types of energy have potential, and we need them together in order to replace fossil fuels.

PHOTOS BY SHUTTERSTOCK

"IF THEY HIT ME, I'LL GET FREE TUITION"

Should we be concerned about the mental health of millenials?

BY LILY WEBER, BIOLOGY AND ENGLISH, 2023

DESIGN BY MARISSA KEESEY, ELECTRICAL ENGINEERING, 2022

It doesn't take long after venturing onto any popular social media platform to fully grasp just how dark millennial humor has become. In fact, listening to any casual conversation among stressed out college students will inevitably yield humor of the same dark, nihilistic variety. Phrases such as "I want to die" or "This class makes me want to shoot myself" are tossed around with the same casual air that someone might inquire about the weather. This type of humor, so shocking and unseemly to older generations, has become commonplace among the millennials, and it's not just surface level in its implications. Numerous recent studies into the mental health of this generation have yielded the same result: Millennial mental health is in serious decline.

In fact, a 2018 study conducted by Blue Cross Blue Shield into major depressive disorders revealed that as overall diagnoses of depression are rising, the rate of depression in millennials is rising even faster. According to the study, the rate of diagnosis for major depression in millennials has increased by up to 47 percent since 2013, compared to an increase of only 33 percent in the general population. Furthermore, Patalay et al in 2019 found evidence that younger millennials have come to exhibit higher instances of both depressive symptoms and self harming or suicidal behaviors. Clearly, millennial mental health is experiencing a serious downturn. The question that remains is why?

Various theories have been proposed to answer this very question. One such explanation relies on the simultaneously declining physical health of millenials. Physical and mental health are very much interconnected. In fact, the 2019 Patalay study also identified that millenials are getting less sleep and have higher body mass indexes, on average. According to the National Institute of Mental Health, those who experience chronic physical health issues are also at greater risk for depression. In other words, worsening physical health could be the root cause of higher rates of depression. The mind-body connection is undeniable. Perhaps worsening physical health has begun to take its toll on millennial mental health as well.

Others blame the rise of social media for rising rates of depression. After all, millenials were among the first to grow up in the internet age. It may follow that this digital engagement has had a profoundly negative impact on their mental wellbeing. The ability to constantly compare oneself with others on social media outlets may lead millennials to feel increasingly dissatisfied with their own lives. A study conducted by Hunt et al in 2018 found that college students made to limit social media usage actually experienced profound decreases in both loneliness and depression. This demonstrates that the rise of social media as a part of our everyday lives may have inadvertently led to mental decline in some of the most tech-savvy of our population. Moreover, as social media content continues to reflect increased depression rates, it perpetuates the very environment that may have led to the increase in the first place.

Another potential cause for increased depression rates in millennials lies in the growing financial burden placed on this generation in particular. Millennials today are facing crippling student loan debt and weakening job stability. According to the National Conference of State Legislatures, as of September 2019 national unemployment was at 3.5 percent. On the other hand, data from the Bureau of Labor Statistics puts millennial unemployment in the same time frame at 8 percent. The economy places a great deal of financial stress on millenials at a time when unemployment is looming. Just as suicide rates saw a sharp spike during the Great Depresson, a similar occurrence may be taking place in current times.

Regardless of whether the true cause is one of these factors or some combination of the three, one fact remains clear: Millenials are depressed. While certain stressors are an inevitable part of life, whether we choose to let depression simply become an unfortunate aspect of millennial culture or decide to actively combat it is up to us, because while millennials may be among some of the least mentally and physically capable of the population, they are also a significant part of what makes up our future.

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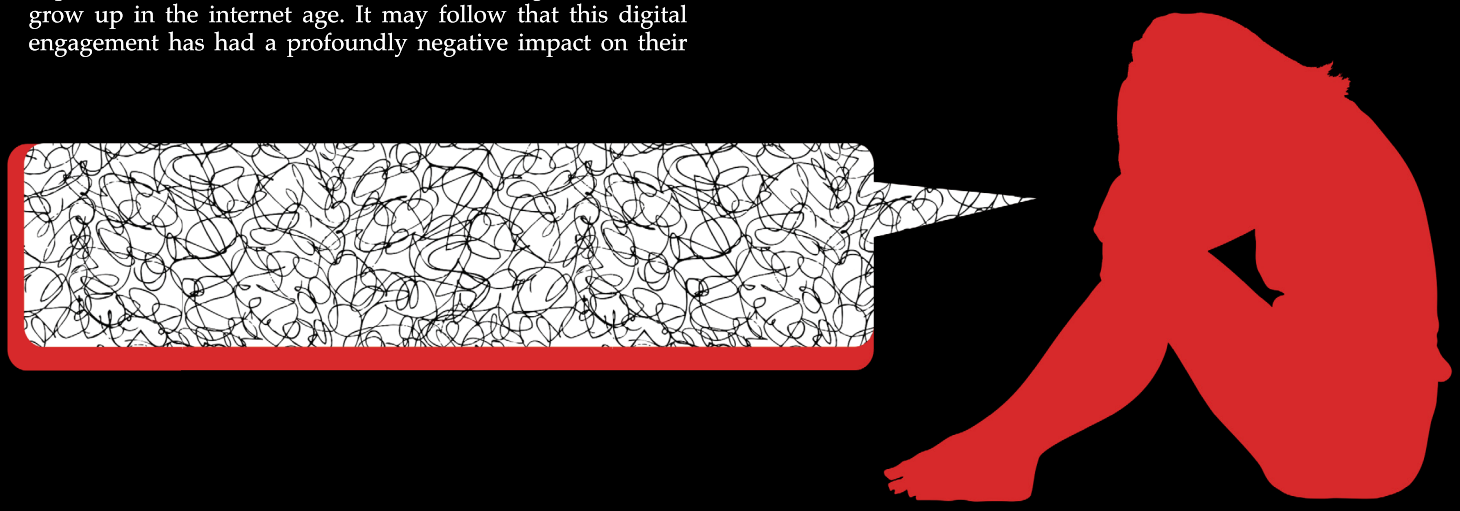

WHY BOSTON BRINGS THE HEAT

Understanding the urban heat island effect

BY ERICA YEE, INFORMATION SCIENCE & JOURNALISM, 2020

DESIGN BY MARISSA KEESEY, ELECTRICAL ENGINEERING, 2022

Boston can feel notoriously hot in the summertime—and it's partially the city's fault. While the climate influences how people develop and use a city, a city also affects regional climate conditions, such as cloud cover, precipitation, air temperature, and wind speed. Within the city, the shapes, spacing, and orientations of buildings also create microclimates that can vary even in the distance of a few meters.

These factors sometimes culminate in the urban heat island (UHI) effect. This phenomenon occurs when the urban air temperature is higher than that of the surrounding rural environment. The effect can be especially apparent at night when cities cool down much more slowly as structures and roads release all the heat they absorbed from the sun that day.

Various potential causes combine to create the UHI effect. Building and street surfaces absorb and trap short-wave radiation from the sun by reflecting between each other. Heat can also be intercepted by buildings that obstruct surfaces from the sky, radiating the heat back into the city landscape. At the same time, air pollution in the atmosphere absorbs and re-emits long-wave radiation, while traffic, heaters, and industries release anthropogenic heat. Evaporation is also decreased because cities are made of less permeable materials and vegetation compared to rural areas.

A 2012 study in the journal *Resources, Conservation and Recycling* proposes several design principles for Dutch cities to mitigate their UHI effects. These strategies, which can be applied to other regions, aim to diminish accumulated heat and apply cooling techniques.

For example, increasing vegetation can help cool the environment actively by evaporation and transpiration, as well as passively by shading surfaces that would otherwise absorb short-wave radiation. This means plants like trees and grass can help cool areas through shade and released water. The four different types of vegetation in urban areas are urban forests (parks), street trees, private green in gardens, and green roofs or façades. Though street trees are typically spread out, their large quantity adds up to a significant impact on temperature within the city. On a sunny day, a single tree cools with the power of 20-30 kW, which is equivalent to that of more than 10 air-conditioning units, according to the study.

Results from a 2016 study by Boston University researchers in *Environmental Research Letters* corroborated this approach by quantifying the interactions between urban vegetation and UHIs in the Boston metropolitan region. The researchers found that, on average, land surface temperatures in Boston were around 7 degrees Celsius warmer and the plant growing season was 18-22 days longer compared to adjacent rural areas. But for parks and other vegetation patches in Boston's urban cores, they observed similar temperature and growth timing patterns to the rural areas. These findings suggest that urban vegetation patches provide a significant ecosystem service and societal benefit in offsetting the UHI effect at the local city scale.

Discovering and implementing these strategies is important because excessive heat can have serious effects on health and well-being to some populations in particular beside general discomfort. Based on a 2015 study in the *International Journal of Disaster Risk Reduction* on social factors that reduce resilience of Bostonians, the city's Climate Ready Boston project identifies social groups especially vulnerable to the impacts of extreme climate and weather events, including heat.

Some age groups like older adults and children are physically more vulnerable to extreme heat. Many people of color, who make up 53 percent of Boston's population according American Community Survey data, may have limited English proficiency and consequently limited access to information about the dangers of extreme heat or resources such as cooling centers. Additionally, people of color often live in more densely populated urban areas which are at higher risk of impacts from the UHI effect.

With the uncertainty surrounding future climate conditions, cities like Boston must continue adapting their environments to mitigate the effects of urban warming and protect the populations that live within them.

International Journal of Disaster Risk Reduction (2015). DOI:10.1016/j.ijdrr.2014.12.001
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Heating up in the Green New Deal

BY CHRISTINA MCCONNEY, BIOLOGY, 2021

We have all heard about the Green New Deal—a ten-year plan proposed to gradually move away from a reliance upon a polluting economy into one that is kinder to the Earth. Reducing carbon emissions and embracing greener infrastructure is beneficial for everyone. From consumers to producers, there is not a single individual who would not benefit from the immensely positive environmental impact that this New Deal would bring.

But what does the Green New Deal mean from a scientific perspective? Political and social impacts are already known to revolve around the creation of new jobs with emphasis on stabilizing and sustaining the current economy. However, the implementation of environmental regulations that would enable the U.S to align itself with other developed countries is promising—the proposed plans are "data-intensive and evidence based," according to an article in the *Archives of Environmental & Occupational Health,* aiming to cut greenhouse-gas emissions to zero.

The plan doesn't solely focus on the environment, with economical attributes at the forefront of the plan as well; however, the "green" aspect is one of the main focuses of the proposed deal. With 69 percent of Americans at least "somewhat" worried about global warming, it makes sense that major portions of the plan focus on environmental impacts. However, there is some hesitation from scientists about the feasibility of the plan. Voices of Ken Caldeira, atmospheric researcher at the Carnegie Institution for Science, and Ernest Moniz, nuclear physicist and Secretary of Energy under former President Obama, express the circulating disbelief of the ability to reach a full net-zero carbon emission within the proposed ten-year period.

Whether or not the net-zero plan is fully accomplished by 2030 as many scientists and politicians are pushing for, the fact remains that action needs to be taken to reduce pollution produced by the U.S by moving towards renewable energy forms. China and Korea have invested 3 percent and 5 percent, respectively, of their total gross domestic product (GDP) towards long-term strategic plans to move their industries to focus around cleaner forms of energy such as solar panels and wind turbines. While the U.S remains stuck in the age of a lucrative but environmentally devastating brown economy, the proposal of the Green New Deal brings new hope to the success of implementation of any environmental regulations. With global temperatures rising to 1.5 degrees Celsius above pre-industrial levels, something needs to change—and soon.

New Solutions (2019). DOI:10.1177/1048291119855671
Archives of Environmental & Occupational Health (2019). DOI: 10.1080/19338244.2019.1608667

PHOTO BY WIKIPEDIA

Congratulations and best wishes from NU Sci!

Editor Hugh Shirley, (Biochemistry, 2019) graduates this December

DESIGN BY LILLIE HOFFART, ENVIRONMENTAL SCIENCE, 2022

PHOTO BY GUS MUELLER, BIOENGINEERING, 2022

NU Sci has been an amazing place to learn and improve throughout my time at Northeastern. As a writer for the past four years and an editor for the past two, I've had my hand in a fair share of articles. One of my favorite pieces I was written as part of a series on students working in labs around campus. I met with different students and learned about their diverse areas of interest, the techniques they're learning, and the PIs that mentor them. My friend, Biruk, had been working in Dr. Lopez's machine learning lab, and the article I wrote about him ended up being retweeted by President Aoun! NU Sci has given me the chance to write and learn about things that I'm interested in, from global surgery to GMOs. As an editor, I've been able to interact with tons of incredibly smart undergrads. It always amazes me how they are able to distill some arcane physical chemistry concept into a fun and engaging article. Editing is a great way to expose yourself to topics that you wouldn't personally be drawn to writing yourself. As I move on from Northeastern towards medical school, I can't help but feel like I will continue honing the journalism skills that NU Sci has given me.

STAFF PHOTO SPOTLIGHT

With a chill in the air, leaves change color and announce the beginning of fall. This maple leaf, found outside Egan Research Center, brings a fiery hue to Northeastern's campus. PHOTO BY GUS MUELLER, BIOENGINEERING, 2022

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