ISSUE 40 Spring 2019

NU SCI

WONDER

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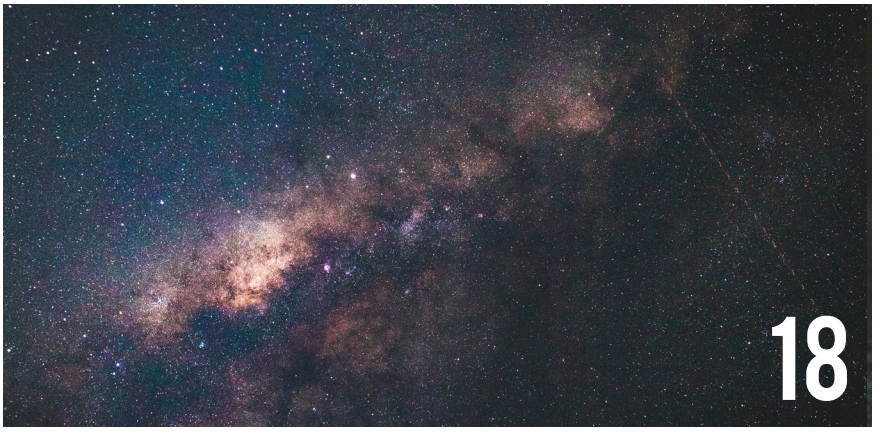


LETTER FROM THE EDITORS

Is there something you've always been curious about? A weird question you've always wanted the answer to? We think we can satisfy those curiosities and inspire many more as our writers dive into the phenomenal and unique questions on their minds. While we continue to celebrate 10 years of science writing and student collaboration at NU Sci, we can think of no better theme to exemplify our members' creativity and diverse expertise.

With that, we are excited to introduce...Issue 40: WONDER.

In this issue, we explore the answers to everything from why people need sleep to understanding cell pyroptosis. Learn about animals like the platypus and the flying squirrel. Or, discover how your brain works to drive imagination and perceive beauty. If these topics leave you wondering still, you can find many more new articles at nuscimag.com.

As we prepare to graduate, we wanted to take a moment to reflect on our time with this amazing club:

> *"NU Sci has been an incredibly special part of my time at Northeastern. In my first semester, I found a group who shared my passion for science communication and gave me a space to learn, try new things, and become a leader. Two dozen articles and five years later, I have been able to cover so many topics since my first piece on the ethics of the beef industry. This magazine has helped provide the networks, experience, and friendships that have and will continue to drive my career forward. It's hard to believe that this issue holds my last article for NU Sci. I am so sad to say goodbye, but so thankful for all of the people and the science that have made Northeastern so great." ~ Sage*

> *"NU Sci has profoundly impacted me as a scientist and a communicator. Throughout my time here, I have had the pleasure of planning our events, running the marketing team, and representing the club as president. I'm so grateful to have found this amazing platform through which I could hone my skills and share my love of science. While this professional development has been incredibly valuable, the friendships I have made along the way mean even more. I feel so lucky to have found such a wonderful group of like-minded nerds who are just as passionate about science as I am. While many of us will be parting ways after this semester, I can't wait to hear what remarkable things this amazing group of people will go on to do!" ~ Jackson*

As this is our last issue, we would specifically like to thank our e-board members and editors for inspiring us everyday with their dedication and enthusiasm. Your friendship, advice, and support mean the world to us, and we are so grateful for the opportunity to work with you all. We wish the next generation of NU Sci leaders the best of luck! We are confident that the magazine will be in great hands, and we are excited to read the amazing stories you will tell.

Jackson Griffiths & Sage Wesenberg
President & Editor-in-Chief

STAFF

Cover Design by Lillie Hoffart

If they can do it, why can't we?

How amphibian research has informed regenerative medicine

BY JACKSON GRIFFITHS, CELL AND MOLECULAR BIOLOGY, 2019

DESIGN BY KRISTI BUI, COMPUTER SCIENCE, 2021

Spinal cord injuries and pathologies are incredibly debilitating diagnoses which often have bleak outcomes and significant impacts on patients' quality of life. The World Health Organization estimates that about 250,000–500,000 people are afflicted by these injuries every year, but —according to the American Spinal Injury Association— current treatments only lead to functional recovery in about 2.1 percent of cases. In response to this clear lack of success with current treatments, researchers are thinking outside the box and turning towards amphibians for answers.

The astounding regenerative potential of amphibian species has captivated researchers since it was first characterized by Lazzaro Spallanzani in the early 1700s. Salamanders, especially those belonging to the Ambystoma family, have been at the forefront of this research due to their exceptional regenerative capabilities. These animals are able to entirely regenerate complex, multi-tissue structures like their limbs and spinal cord segments. Given that these tetrapods are distantly related to humans, many believe that the same regenerative potential could be unlocked in human patients.

Despite decades of study, the exact mechanisms by which salamanders regenerate has long eluded researchers. Fortunately, recent advancements in genetics, transcriptomics, and fluorescence imaging have led to rapid growth in our understanding of the cellular processes and signaling pathways unique to amphibian injury responses. We now know that there are three crucial components of the amphibian regenerative response which mammals lack.

The first is populations of tissue-specific progenitor cells. These adult stem cells normally lie dormant within tissues, but, in response to injury, they begin to proliferate and replace lost cells. For example, muscle tissues in adult axolotl salamanders contain dispersed populations of Pax7+ myocytes. When regenerative programs are initiated in response to a critical injury, these muscle progenitor cells begin rapidly dividing. Numerous studies have used lineage tracing, a technique which labels a given cell and all of its progeny, to confirm that these cells rapidly proliferate and differentiate after injury, eventually forming all of the muscle cells in a regenerated structure.

Amphibians also differ from mammals with regard to how their immune system responds to injury. In humans, when the spinal cord suffers acute damage, there is a massive influx of immune cells and inflammatory signals. These immune cells begin eating up cellular debris and releasing cytokines, which are signaling proteins that trigger and exacerbate the inflammatory response. This inflammation attracts astrocytes, a form of glial cell, which accumulate within the wound site and produce a physical barrier referred to as a "glial scar." This combination of inhibitory signaling with a physical barrier makes it impossible for axon fibers to traverse the site of injury. Without axonal outgrowth, neurons cannot re-establish the connections needed to produce functional recovery. In contrast, when the spinal cord of an axolotl is injured, immune cells still respond, but instead of promoting inflammation they secrete pro-proliferative signals and clear up debris to facilitate the replacement of damaged cells.

The third essential component of the salamander injury response is the activation of neurotrophic signaling pathways, which promote new growth and survival of neurons. For nearly a century, the identities of the neurotrophic factors unique to amphibian regenerative responses have eluded discovery. Luckily, considerable progress has been made in this respect, and several signaling molecules have received strong support suggesting their importance for facilitating neuron growth and recovery after injury.

Armed with this new knowledge, researchers have begun to develop novel treatment regimens which attempt to mimic the pro-regenerative conditions seen in amphibians. One study conducted in primates at the University of California, San Diego found that functional recovery after spinal cord injury could be achieved if: (1) the glial scar was removed; (2) neural stem cells were injected; and (3) a "cocktail" of neurotrophic growth factors was added. Studies like these provided the first evidence that the knowledge we gain from amphibians can likely be translated to human treatments.

In response to these breakthroughs, several clinical trials have been started to determine just how effective these treatments may be in human subjects. While it is still unclear exactly how translatable amphibian research may be to human medicine, it is unlikely that the fascinating regenerative abilities of our small, slimy friends will ever stop being a source of wonder to those who study them.

Nature Medicine (2018). DOI: 10.1038/nm.4502

PHOTO BY GUS MUELLER

Fluorescence in flying squirrels

BY MEGAN WASSICK, ENGLISH, 2019

Imagine walking through the woods at dusk and seeing, gliding across your path, a flying squirrel glowing bright pink.

Because of the limitations of the human eye, this would simply never happen to you. The experience was happenstance for researcher Jonathan Martin of Northland College, Wisconsin, who was using an ultraviolet flashlight to observe plants and lichen, only for a southern flying squirrel flying by to be illuminated in hot pink. Ultraviolet (UV) rays, which have a shorter wavelength than visible light, can produce certain types of fluorescence, like in the flying squirrel, that will remain undetected to the human eye without special tools.

Martin and a research team examined specimens of the three species of North American flying squirrels: the southern, northern, and Humboldt's flying squirrel. 109 museum specimens, collected across more than 100 years, were photographed under UV light. 108 of them had fur that is in some degree fluorescent. Five living specimens observed in the wild displayed fluorescence in the same manner as the museum specimens.

But why the glow?

There are several possibilities. It may be an adaptation for low-light conditions: unlike other North American squirrels, these three flying squirrel species are most active during dusk and night, and do not hibernate during the winter. Ultraviolet rays are more common during the night and UV vision is an asset to many other nocturnal mammals. In winter, the amount of UV radiation that reaches the earth from the sun is doubled. Initial study of the eye lenses of the southern flying squirrel show that they can transmit UV light and likely have better low-light vision than other squirrels.

Their fluorescence may also have developed as a way to signal to others of their species, like showing their movement patterns while they glide, or contributing in some way to the selection of mates. Or it may be meant to communicate not within their species, but to fool those outside of it: several species of owls that live in the same range and prey on the flying squirrels, such as barn owls, barred owls, and great horned owls, show similar pink or magenta UV fluorescence. The fluorescent squirrels may have adapted to mimic these predators and avoid their notice.

While more research is required to illuminate the answer, or combination of answers, as to why these squirrels glow, it's something to keep your eyes open for!

Journal of Mammalogy (2019).
DOI: 10.1093/jmammal/gyy177

MOLA MOLA: MO' PROBLEMS

BY TORI MARKIN, BUSINESS ADMINISTRATION, 2021

The deep sea is full of mysterious creatures, and the Mola Mola is no exception. The Mola Mola's name reflects its unusual appearance—"Mola" being the latin word for "millstone," a giant grey stone used for grinding wheat. When looking at the Mola Mola from an evolutionary standpoint, it's hard to grasp how this parasite-ridden, clumsily-swimming fish with a hefty appetite has managed to survive the tides of natural selection.

The Mola navigates the deep sea at a leisurely two miles per hour, due to its lack of a tail to use to propel and steer its massive body. The Molas' slow swimming makes them extremely vulnerable to over fifty genera of parasites, which have become their main predator. Their huge bodies combined with their diet of mainly low-nutrition jellyfish means they are forced to consume around 2600 tons daily. This jellyfish snacking habit is not only inefficient, but also painful. With the Mola's nut-sized brain, it does not seem like it has won the evolutionary lottery.

The Mola Mola quietly maintains the title of the heaviest bony fish. The average Mola Mola weighs about 2200 pounds, but the largest spotted was off the coast of Japan, weighing just over 5000 pounds. Without a legitimate tail, they use their large anal and dorsal fins like a rudder to awkwardly maneuver themselves. Efficient? Absolutely not. But it works.

Despite the Mola Mola's slow swimming, its size gives it a considerable advantage over their fellow ocean inhabitants, so its only consistent predator is parasites. But fear not for the health of the Mola Mola. Seagulls and Molas have developed an unlikely symbiotic friendship, in which seagulls snack on the dozens of parasites that prey on the Mola while it sunbathes. Sunbathing also helps regulate the Mola's body temperature after long dives for food.

While the Mola's diet of jellyfish may seem unbearable, it also sports a thick layer of mucus instead of scales, which mitigates the pain of the jellyfish sting.

And if that wasn't enough to keep the Molas alive and well, the female Mola lays more eggs than any other vertebrate at three hundred million eggs at a time. You might not like the Mola, but at the very least, you should respect its tenacity.

PHOTOS BY PUBLICDOMAIN.NET & PEXELS.COM

DESIGN BY KAI GRAVEL-PUCILLO, ENVIRONMENTAL SCIENCE, 2021

ROLLING IN THE DEEP:

How marine animals quench their thirst

BY SINAIA KEITH LANG, BIOLOGY, 2022
DESIGN BY LILLIE HOFFART, ENVIRONMENTAL SCIENCE, 2022

What if you lived in water? Would you be constantly searching for something to quench your thirst or would you constantly feel the relief that comes with an end to the parched feeling? The answer: it depends. Fish and other marine animals, like all living things, need water—the universal solvent—to survive. Vertebrates in particular, including fish, mammals, reptiles, amphibians, and birds, require a dissolved salt concentration of 0.9 percent. How those animals that live in water maintain this concentration, however, varies from species to species and from environment to environment.

Freshwater fish, such as goldfish, live in water that is hypotonic. This means that the concentration of dissolved substances in their tissues is higher than in their environment. As a result, the water is constantly trying to diffuse into the fish's tissues to attain equilibrium, that is, to balance out the difference in concentrations. In response, freshwater fish are constantly urinating to remove excess water from their bodies. Their urine is extremely diluted in order to retain their salinity. Additionally, the cells in their gills have adapted to collect more salts than human cells do.

In sharp contrast, bony saltwater fish, such as tuna, live in water that is hypertonic, meaning that the concentration of dissolved substances in their tissues is lower than in their environment. The fish seep water out of their tissues in a process known as osmosis. To compensate, saltwater fish constantly consume water. Marine fish have an enzyme in their gills that helps them pump the excess salt out of their bodies. The kidneys of marine fish have also evolved to excrete surplus salts via extremely concentrated urine.

Freshwater and saltwater fish species that cannot tolerate changes in salinity are called stenohaline species ("steno" meaning narrow and "haline" meaning salt). Should a tuna swim into a freshwater stream, it would die. The opposite, euryhaline species ("eury" meaning wide), can survive a range of salinity. Salmon, for example, are born and spawn in freshwater but spend the majority of their lives in the sea. These animals retain the adaptations found in both freshwater and saltwater fish, although they do need some time to acclimate to the changes in their environment (like humans getting over jet lag). This usually occurs in the time it takes the fish to swim through the brackish waters that lie between the two environments.

> "How those animals that live in water maintain [salt concentrations] varies from species to species and from environment to environment."

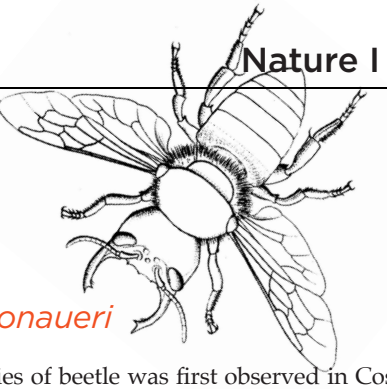
Marine mammals, like sea lions and whales, have kidneys that have adapted to increase the amount of water recovered from the blood that filters through them, much like saltwater fish. Unlike saltwater fish, however, marine mammals rarely drink water. Because marine mammals are mostly carnivores, their diets consist of animals with the same concentration of salts in their tissues. Unlike mercury, a toxic substance that increases in concentration as it travels up the food chain in a process known as biomagnification, salt concentrations remain at 0.9 percent because the mammals get additional water as a byproduct of the breakdown of nutrients. As such, their blood salinity remains fairly constant. On occasions when their blood salinity is too high, some marine mammals will drink water, but it is very rare.

Sharks and rays in saltwater use an approach that differs immensely from those of other aquatic organisms. Sharks and rays produce huge amounts of urea, which is usually excreted in urine as a waste product from the breakdown of proteins. The concentration of urea in their tissues is about the same as the concentration of salt in their environments, so water does not need to travel into or out of the animals' cells. In this case, the animals are living in an environment that is isotonic to their tissues. If water is needed, it is absorbed, along with its dissolved salts, through the gills. Any excess salts that accumulate are removed from their bodies via their digestive systems.

Comparatively, land-dwelling humans require the ingestion of three to four liters of water per day. This is your friendly reminder to drink water; it maintains salinity concentrations at a healthy level, so our tissues and cells remain in their isotonic, balanced environment. Stay hydrated, friends!

PHOTO BY MELANIE CHADWICK

An unknown world



BY YASMINE MYFTIJA, BIOLOGY, 2021
DESIGN BY KYLA VIGDOR, DESIGN, 2021

It's estimated that only five percent of the world's seafloor has been mapped out, leaving the other 95 percent undiscovered by mankind. And while almost all of the Earth's land has been visited or inhabited by people, new species continue to be found in remote areas. Even more surprisingly, areas well-traveled by people, including New York City's Central Park, have been known to host undiscovered species in recent years. In 2018, scientists all over the globe discovered over 200 new species of plants and animals, many of which remain mysteries to the scientific communities. Here are some of the unique organisms uncovered just last year:

Hippocampus japapigu

Also known as the "Japan pig" seahorse, this sea creature is roughly the size of a jelly bean and has a coloration that allows it to blend into the reefs of southeastern Japan. It has two protrusions on its neck that bear a striking resemblance to wings, but the function remains unknown. This newly discovered pygmy seahorse calls the algae and soft coral reefs surrounding Japan its home, and it is observed less frequently than their counterparts in the *Hippocampus* genus.

Miconia rheophytica

Found along a river in the Colombian Andes, this newly discovered plant species produces a sky-blue berry that is thought to drop into the river, subsequently being carried down and embedded into a new spot where another plant can grow. However, the plant is already listed as an endangered species by the International Union for the Conservation of Nature (IUCN) and faces other imminent threats. The surrounding area may become a construction site for a hydroelectric dam in the next few years, the effects of which could wipe out the species in the region completely.

> "With an unknown world full of new creatures just waiting to be discovered, it looks like scientists' work is just beginning."

Nymphister kronaueri

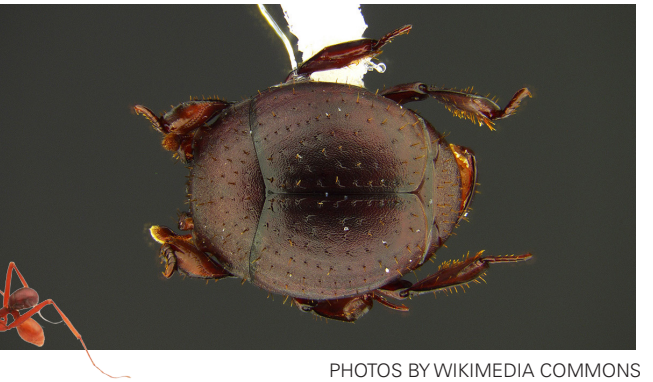
This fascinating species of beetle was first observed in Costa Rica. The miniscule brown beetle hitches a ride on the army ant, *Eciton mexicanum*, blending in completely as it mimics the shape and color of the ant's abdomenal region. It clamps down onto the ant's body with its mouth and takes a rest as the ant walks for the both of them. The beetle can detach from the ants, walking around and feeding until their nomadic hosts move on. Ants with the beetle attached to their body can be distinguished by appearing to have two abdomens instead of one. *N. kronaueri* is also thought to use chemical signals, but scientists are still attempting to figure out how the beetle keeps itself from falling prey to others.

Megachile pluto

A bee that was thought to have been extinct has been rediscovered in Indonesia. *Megachile pluto*, commonly known as the Wallace Giant Bee, has a body comparable to the size of a thumb and a similarly large wingspan. It was considered the world's largest bee and was thought to have been extinct since its last sighting in 1981. Megachile pluto has only been found on three Indonesian islands, but the habitats of these bees have drastically changed over the years; oil palm plantations have taken over the region, raising concerns for the safety of these bees. The bees have even been labeled as a vulnerable species by the IUCN.

M. pluto also have an extremely large set of mandibles and are likely able to sting. Curiously, males and females of the species show sexual dimorphism, meaning that they have different characteristics in addition to their sex organs. Females grow much larger than their male counterparts and only the former have large jaws. While the prospect of giant bees may not be exciting for those with phobias, the rediscovery of *M. pluto* in its natural environment, which had been threatened by widespread deforestation, is thrilling to biologists.

Last year was full of bizarre and fascinating discoveries. Even so, scientists believe that only one-fourth of all species on Earth have been discovered. With an unknown world full of new creatures just waiting to be found, it looks like scientists' work is just beginning.



PHOTOS BY WIKIMEDIA COMMONS

Nature's symphonies:

How songbirds create complex melodies

BY ROXANNE LEE, ENVIRONMENTAL SCIENCE & POLICY, 2019

One of most popular signifiers of spring is the sound of bird song finally breaking the long winter silence. But how do they create such beautiful sounds, and why do they do it?

The birds typically imagined when thinking of birds singing are songbirds. These are part a group of about 70 families of birds in a clade—line of descendants—called Passeri, associated with melodic, complex songs.

The term "bird song" refers to complex vocal patterns with clear structure and rhythm created by a bird that serve a specific function, as opposed to "bird calls," which are short, simple, innate vocalizations.

Songbirds produce their songs via an organ called a syrinx, or lower larynx, found at the base of the trachea where it splits into dual bronchial tubes. The muscles of the syrinx manipulate air as it flows through the trachea, producing sounds. Each of the two branches of the syrinx is individually controlled, allowing birds to simultaneously create two unrelated pitches, essentially allowing them to duet with themselves and sing incredibly complex songs. The Wood Thrush, for example, can sing simultaneous rising and falling notes in its song.

Most of what we know about song development in songbirds comes from the study of male zebra finches. Songbirds learn their songs through two developmental periods. In the first period, the sensory period, fledgling birds listen to the songs of their fathers and male adults around them. Following this is the sensorimotor period, a period of intense practice when the bird practices its own song. The practice songs are unstructured and messy, before they are refined into one resembling that of its community. Even when raised in isolation, zebra finches still sing, but their song structures do not resemble those of their wild relatives'.

Songbirds sing for a variety of reasons: to claim and establish territory, impress a mate, establish social bonds, and generally communicate.

Bird song may have risen in part due to their surrounding environment. Birds that sing typically find mates in low-visibility areas, like thick woodlands, where auditory cues are more likely to be picked up by potential mates than visual cues.

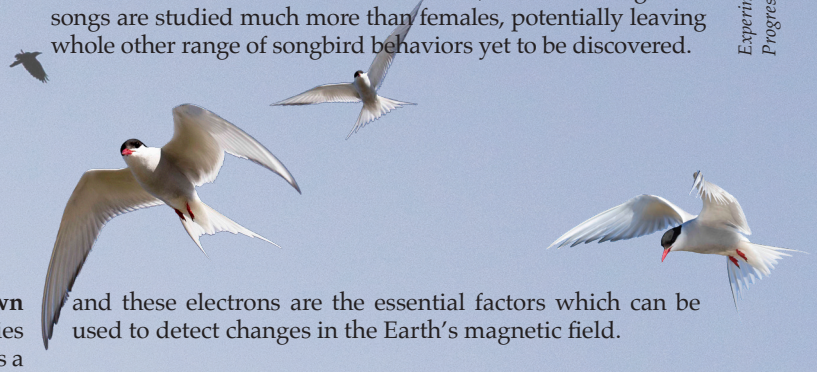
There is still much to learn about bird songs—why birds sing in a dawn chorus is not well understood, and male songbirds' songs are studied much more than females, potentially leaving whole other range of songbird behaviors yet to be discovered.

Experimental Animals (2015). DOI: 10.1538/expanim.15-0008
Progress in Brain Research (2014). DOI: 10.1016/B978-0-444-63488-7.00015-X

Smart soaring:

The inner compass of birds

BY OLIVIA CLAUSEN, ECONOMICS & ENVIRONMENTAL STUDIES, 2021



While many humans cannot navigate their own city without the help of a GPS, some bird species such as the Arctic fern can fly nearly 50,000 miles a year without the aid of any map. This spring, more than 4,000 species of birds will migrate to regions with abundant food and areas to nest, guided only by their internal compasses. These "internal compasses" are essentially the various physiological traits that migratory birds have which allow them to complete their impressive journeys.

One of the most common navigational approaches is to fly along celestial and geomagnetic routes created by Earth's magnetic fields and the sun. A study conducted on the behavior of robins at Goethe University in Frankfurt, Germany concluded that birds have "a light-dependent compass in their eyes", which allows them to determine the direction of the Earth's magnetic field. According to test results, this "compass" consists of a special protein in their eyes called cryptochrome, which uses energy absorbed from UV wavelength light to produce the co-enzyme FADH-. FADH- subsequently generates two free electrons, and these electrons are the essential factors which can be used to detect changes in the Earth's magnetic field.

Birds are also able to migrate through the use of olfactory navigation, a form of navigation in which cues from unique scents are used to guide an animal's movements. Research conducted by the Italian ethologist Floriano Papi on homing pigeons revealed that birds create an olfactory map when they fly from their home location to another. This map familiarizes them with landmark scents along their route and allows them to return home using their sense of smell. When the homing pigeons were taken to a new place without flying there themselves, they were completely disoriented and had no means of returning home—demonstrating how essential their olfactory abilities may be.

Exactly how birds migrate continues to be a matter of debate due to the number of ways in which this navigation may be facilitated. While the mechanisms by which these birds find their way may differ, their migration continues to be a source of wonder for many of us.

Journal of Experimental Biology (2014) DOI: 10.1242/jeb.116939

PHOTOS BY GUS MUELLER, FLICKR, AND PIXABAY

DESIGN BY KYLA VIGDOR, DESIGN, 2021

What's at the bottom of the ocean?

Taking a dive into the deep

BY CHRISTINA MCCONNEY, BIOLOGY, 2021
DESIGN BY KRISTI BUI, COMPUTER SCIENCE, 2021

Everybody wonders about what is at the bottom of the ocean, and throughout history many have attempted to answer this daunting question. However, their efforts to uncover the mysteries of the ocean floor have made barely a dent in uncovering what actually lurks down below. The ocean makes up 70 percent of the earth's surface, and with nearly 80 percent of it remaining uncharted and unexplored, it's no wonder that humanity has struggled to come to a conclusion of what actually resides down in the sea bed.

Despite the discouraging lack of exploration and documentation of this vast body of water, the 20th century brought about a wave of curiosity that has continued into today's society—aiming to explore and explain, mile by mile, exactly what we can expect to find at the bottom of the ocean. From shipwrecks to alien-like life forms, glowing fish to microorganisms, piece by piece the jigsaw puzzle that is the ocean floor is being put together.

In the mid-19th century, Edward Forbes developed his azoic hypothesis: declaring that no life existed in the deep ocean. Noticing a trend in the decrease of plant and animal life with the increase of ocean depth, he hypothesised that life would altogether cease to exist closer to the ocean floor. The azoic theory was held to be true for 25 years; the rationale at the time concluding that the large amounts of pressure, cold, and total absence of light wouldn't allow for the sustainability of life. Today, thanks to the technology and knowledge available, we know that the ocean floor is bustling with life—if you know where to look.

Deep oceans most noticeably lack light and warm temperatures, making the existence of life at such depths seemingly impossible. However, there is a large ecosystem that thrives in these benthic environments, living around hydrothermal ocean vents and almost appearing to defy the laws of nature. Meiofauna—small invertebrate inhabitants of the benthic zone—are diverse across different layers of the ocean floor; varying most prominently in response to temporal differences. In the depths of the Mid-Atlantic, mussels are one of the most common types of thermal vent dwellers seen in colder temperatures. Venture into warmer temperatures, and crustaceans begin to emerge as the dominant life form.

Vanhoeffenella, a genus of deep sea monothalids, are dispersed generously among the bustling sea floor and have been documented in texts since the start of ocean exploration. Easily identifiable by their characteristic eye-like appearance, these creatures are found on the ocean floor all over the world. However, despite their widespread presence in both the ocean and history, there is hardly anything known about their diversity. In 2017, a team of scientists from the University of Southampton, Waterfront Campus decided to investigate and hopefully shine some much needed light on these deep sea dwellers. The team was ultimately able to identify ten distinct species within the genus, adding to the four previously known and increasing overall knowledge as to the nature of the species.

The deep ocean isn't only limited to living inhabitants: a number of inanimate objects litter the ocean floor and contribute to mystery that surrounds the deep blue depths. Shipwrecks lay scattered all over the ocean floor, many of them remaining unknown to the surface world. The deepest one, making a name for itself in the Guiness Book of World Records at a depth of 18,904 feet, was found resting at the bottom of the South Atlantic Ocean. The SS Rio Grande, a German Blockade Runner used in WWII, was discovered in 1996 by Blue Water Recoveries and serves to show that aquatic life is teeming with much more than just living organisms.

> "The ocean makes up 70 percent of the earth's surface and with nearly 80 percent of it remaining uncharted and unexplored."

Despite the unearthing of the tenants residing at the bottom of the deep blue sea—both animate and inanimate—there are still a large quantity of organisms and artifacts left to be found. Discovery of different marine life is being relentlessly pursued around the world, spurred on by the looming threat of global climate change drastically affecting the ocean's trophic levels. With natural human curiosity as a catalyst, we are diving deeper and deeper into the secret life that exists at the bottom of the ocean.

Endeavour (2006). DOI:10.1016/j.endeavour.2006.10.003
Protist (2018). DOI:10.1016/j.protis.2017.11.003
Deep Sea Research Part II: Topical Studies in Oceanography (2017). DOI:10.1016/j.dsr2.2016.05.028

PHOTO BY PIXABAY

Have pouch, will carry:

NU Sci explains kangaroo pouches

BY RAFI RAZZAQUE, ENVIRONMENTAL SCIENCE, 2019

Why do kangaroos carry joeys in their pouches? Put simply, underdeveloped offspring. Kangaroos, along with wallabies, koalas, and wombats, are classified as marsupials. The defining characteristic of animals in the infraclass *Marsupialia* (derived from the Latin term *marsupium*, meaning "pouch") is the way they carry their young in a pouch post-birth.

All marsupials have short gestation periods: the red kangaroo, largest of all kangaroos, delivers a lima bean-sized neonate after 30–35 days, but other marsupials have a gestation period as low as 12 days. The kangaroo neonates are born underdeveloped and blind and crawl from one of the mother's two uteri into her pouch. From there, the joey nurses off one of the mother's four teats, which has the effect of starting the mother's cycle once more.

After about 180 days, the joey will be large enough to emerge from the pouch; before then, you might catch it poking its head out from time to time but never leaving fully. Around 230 days after birth, the young kangaroo will leave the pouch for the last time. A mother kangaroo will also push off her offspring to dissuade it from returning to the pouch at this point. Given that a mother kangaroo handles up to three joeys in various stages of development (one in an egg state, one in a neonate state in the pouch, and one independent of the pouch but still breast fed), the mother likely already has another joey dependent on her pouch.

As for *how* kangaroos and other marsupials ended up with pouches—that remains a challenge to explain. Pouches are not bone structure and are not observable in fossil records. Additionally, DNA evidence from marsupial ancestors does not exist. Researchers have questioned whether pouches enable the mother to incubate several offspring at various development stages in difficult, dry conditions. Additionally, the time and energy kangaroos spend foraging for food may have lead to a selection for smaller, underdeveloped embryos at birth. Lastly, pouches offer the young a degree of protection from predators; pouch development may have been selected by survival rates of joeys that utilized a pouch.

While the evolutionary necessity of marsupial pouches is a bit unknown, the fascinating ways mother kangaroos develop their young in pouches definitely set them apart from most mammals. Not unlike us, marsupials carry their protected, precious, and enchanting offspring in publicly observable ways. And good thing they do!

Which hand has the upper hand?

BY NATALIA CHAVEZ, CELL & MOLECULAR BIOLOGY, 2021

To those who have heard or used the phrase, "Only left-handed people are in their right mind," you are actually not that misguided. People with left-hand dominance depend on the right hemisphere of their brain for movement and coordination, and vice versa for those who are right-handed. According to a 2014 study published in *Frontiers in Psychology*, 85 percent of people consider themselves right-handed, with the rest claiming left-hand dominance. But what is the cause of this phenomenon? Why is the majority of the population right-handed, and what, if any, are the results of acquiring such a trait?

The answer involves both the evolution and genetics of the human race. A study led by Valentina Parma and Professor Castiello from the University of Padua discovered that hand preference develops in the womb as early as 18 weeks. What makes more than three-fourths of the population right-handed, though, involves evolutionary natural selection. We depend on the left hemisphere of our brain for motor control in our right hand. Perhaps by no coincidence, the left hemisphere of the brain is also responsible for language production. The synchronization of having the left hemisphere control the movement of the right hand *and* be responsible for the production of written language is thought to be an evolutionary advantage. This dual functioning reduces the amount of cross communication needed between the two hemispheres in right-handed people.

With regards to the genetic theory behind hand preference, scientists have begun to explain the existence of two alleles that are associated with brain dominance. The pair of alleles go by the names of D and C genes. The dominant allele, in this case, is the D gene, and is the one that leads way to right-hand dominance. The C genes are a minority in the gene pool, but are still present as they are not necessarily harmful to the organism. This is the reason why, although there are few, they are still present in society.

Overall, both theories are interesting in that they show the collaboration of internal and external factors that affect an organism in its entirety. With a trait as harmless as a dominance in either the right or left hand, scientists are able to take note of how intricate the human body really is and how susceptible it is to environmental and societal pressures.

Frontiers in Psychology (2014). DOI: 10.3389/fpsyg.2014.00082

DESIGN BY KYLA VIGDOR, DESIGN, 2021
PHOTOS BY PIXABAY

Ophidiophobia: why you may have it

BY LUCAS PRINCIPE, ENVIRONMENTAL SCIENCE & PHILOSOPHY, 2020

Ophidiophobia, or the fear of snakes, is consistently listed as one of America's top aversions, along with public speaking, heights, needles, and small spaces. Most notably, a 2001 Gallup poll found over 50 percent of Americans fear these serpentine reptiles—even though most Americans probably don't interact with them on anywhere near a regular basis.

I actually own a pet snake. A three-foot-long Ball Python. He's a lovely pet. And he loves to wrap himself around my neck and crawl through my shirt. I've never been afraid of him. But whenever I take him out of his cage around other people, I watch them recoil. If it's a boring day at home, I still chase my mother around the house with him while she shrieks. It's these kind of reactions that made me wonder, why are so many people afraid of snakes?

Surprisingly, there has been a large amount of early developmental research conducted on this phenomenon. The two competing schools of thought are as follows: humans have an innate fear of snakes; or, humans have an evolved predisposition to *associate* fear with snakes, though the actual fear is not innate. Both of these theories build off the fact that snakes posed a serious threat to our ancient human ancestors. An encounter with one 50 million years ago, before modern medicinal measures such as antivenom, could easily leave a primate dead.

One 2017 study by researchers at the Max Planck Institute for Human Cognitive and Brain Sciences, published in *Frontiers in Psychology*, recorded the pupil dilation reaction in six-month-old infants when shown photos of evolutionarily threatening and non-threatening species. The researchers chose to study this response due to the pupils' connection to the same neural system—the noradrenergic system—that produces stress in an individual.

The team found infants reacted with larger pupil dilation when shown photos of spiders and snakes as opposed to photos of flowers and fish—suggesting a fear of these animals may be innate in humans.

"It's a very long period of coevolution—nearly 40 to 60 million years of it, that early human ancestors and spiders and snakes have interacted," lead researcher Stephanie Hoehl explained to National Geographic. The study concluded that an innate fear of snakes could be an evolutionary defense mechanism against a potentially lethal bite.

Other research, however, remains more skeptical about this claim. A 2008 study published in *Developmental Science* used an auditory-visual matching paradigm with infants aged 8–16 months. The infants were simultaneously presented two films—one of a snake and the other of an exotic animal—appearing with the recording of either a happy or a frightened human voice.

The researchers hypothesized, "if infants have a predisposition to associate snakes with fear…they should look longer at snakes when they hear a frightened voice." And the team's data revealed just that—there was a significant tendency in infants to associate snakes with fearful stimuli.

"What we're suggesting is that we have these biases to detect things like snakes and spiders really quickly, and to associate them with things that are yucky or bad, like a fearful voice," said Vanessa LoBue, co-author of the study, to Science Daily.

The research suggests that humans can both detect and learn to be afraid of snakes more quickly than other animals. However, the data does not support the hypothesis that the fear of snakes is necessarily innate.

Regardless of the answer, a growing segment of the population is turning away from traditional pets, such as cats and dogs, and embracing scaled species instead. Between 2007 and 2012, the number of American households that own a pet snake increased by 42 percent, according to the American Veterinary Medical Association. In the United Kingdom, the British Federation of Herpetologists estimates that, as of 2008, there are 1.5 million more reptiles than dogs being kept as pets.

With numbers like these, it's increasingly likely that at some point in your life you'll find yourself walking into the living room of a new friend to find a 10-gallon tank equipped with a heat lamp and a python sitting underneath it. When that happens, overcome your evolutionary tendencies, be calm, and ask to hold it. I promise you'll be surprised how friendly they can be.

Frontiers in Psychology (2017), DOI: 10.3389/fpsyg.2017.01710
Current Directions in Psychological Science (2010), DOI: 10.1177/0963721410388801

PHOTOS BY LUCAS PRINCIPE AND PIXABAY

DESIGN BY KYLA VIGDOR, DESIGN, 2021

Laughter:

The mechanism behind the best medicine

BY PAULA HORNSTEIN, BIOCHEMISTRY, 2020

Imagine you are an alien visiting Earth. In a conversation with a human, you tell a knock-knock joke. The human responds to this by emitting rhythmic, repetitive noises from deep inside their bodies, seemingly by impulse. You later tell someone else the same joke, and receive the same response from a different human, although the noises he makes are slightly different and have a different rhythm. You think, Why do they do this?

What causes this shared human reaction to something humorous? This is a subject of wonder spanning as long as humans have been laughing. In 1922, an article was published in the popular twentieth-century science magazine, The Scientific Monthly, entitled Why Do We Laugh? In this piece, Professor Wilson D. Wallis of Reed College addresses the sociological and theoretical evolutionary reasoning for our impulse to laugh. According to Wallis, laughter is both a social phenomenon and a language in and of itself. Laughter as a physical response is two-fold: it is uplifting for the individual and provides for social solidarity. While laughter is not necessarily reserved for only humorous situations--cue nervous laughter, or boastful laughter--it is representative of a person's understanding of a joke, an anecdote, or a situation, giving humans a sociological reason for their reflex to let out a titter.

Since this publication, much of the scientific reasoning for laughter has been discovered. Real laughter requires a stimulus, either internal or external. This stimulus activates the ventromedial prefrontal cortex, and the stimulus processed by multiple regions in the brain, including the hippocampus and amygdala. Many theories of the precise neural pathway of laughter exist, and are still being studied to this day.

A human's physiological reaction to this stimulus is rhythmic, continuous contractions of the diaphragm. The regular proceedings of respiratory system are disrupted, causing the audible gasps that are characteristic of any laugh. A particularly intense bout of laughter can disrupt ventilation to such an extent that the person can turn blue as a result of hypoxia, or possibly activate the tear ducts. In fact, there are at least ten records of people who have "died of laughter," usually due to a dangerously high respiratory rate that resulted in heart failure. The truth behind these stories are questionable, but there is no doubt that the mechanism behind laughter involves inherent disruption of homeostasis within the body.

Despite the risks involved in laughter, laughter can certainly not be considered a dangerous act. In addition to its social benefits, laughter has been shown to have beneficial effects on the brain and the body alike, such as reducing stress hormone levels, releasing endorphins, relaxing the muscles, and lowering blood pressure. While laughter may not be the best medicine, it certainly provides health benefits that make it worth acknowledging the humor in the world.

Evolved from greatness:

Studying the Grandmother Effect

WRITTEN AND DESIGNED BY LILLIE HOFFART, ENVIRONMENTAL SCIENCE, 2022

Why do humans live long after their years of child-bearing? Few other species experience the social connections humans do with their grandparents. A hypothesis known as the Grandmother Effect suggests this is not due to advances in healthcare, but rather is an integral aspect of human survival.

University of Utah Anthropologist Kristen Hawkes is one of the leading advocates for this phenomenon. Her interest in the Grandmother Effect was sparked in the 1980s while on two field projects studying the behavioral ecology of hunter-gatherer populations in Paraguay and Tanzania. Grandmothers spent much time harvesting food for their grandchildren. From this, Hawkes concluded this event explains why humans have evolved to live long after their reproductive years. In earlier years, grandmothers could help provide for their grandchildren, which would allow the children's mother to devote herself more to the next baby. "Vigorous grandmothers could help more and leave more descendants," Hawkes wrote in a 2012 mathematical population analysis. Therefore, the most evolutionarily-fit grandmothers will pass on their longevity genes to the greatest number of grandchildren.

In a study combining data collected from great apes and hunter-gatherer populations, Hawkes, along with other researches, developed models illustrating differences in population growth and lifespan with and without grandmothering. On average, a theoretical population with birth intervals resembling those of apes — meaning no grandmothering — were 5 years between offspring. Added grandmothering decreased that to three, as mothers would hand off their children to grandmothers as the youngsters reached age 2. Comparing ape-like life expectancy to one with grandmothering, the new expectancy doubled — from 25 to 50 years. Hawkes proves that "grandmothering can move life spans from the great ape to the human range." The added childrearing help offered by a grandmother makes all the difference in early humans success.

This is just another reason to celebrate grandmas. So the next time grandma prepares lunch, slips you a five dollar bill, or tells you to put on a sweater, remember she is looking out for you.

Nature (2004). DOI:10.1038/428128a
Royal Society (2012). DOI:10.1098/rspb.2012.1751

PHOTOS BY FLICKR, UNSPLASH

WHAT CAUSES A DISTRUST IN SCIENCE?

BY MAYA KRAUSE, ENVIRONMENTAL SCIENCE, 2022
DESIGN BY LILLIE HOFFART, ENVIRONMENTAL SCIENCE, 2022

I grew up in the San Francisco Bay Area, where the percentage of people who believe that climate change is real is 12 percent higher than the national average, according to a 2018 survey from the Yale Program on Climate Change Communication. But when it comes to vaccinations, Bay Area residents are notoriously unsure. On average, the rate of vaccine refusal in the Bay Area is 8 percent, compared to the vaccine refusal rate of 2.5 percent in the rest of California, according to a 2015 report published in Pediatrics. This puts the Bay Area at an elevated risk for outbreaks of preventable diseases like whooping cough or measles. Growing up in a community with this dynamic led me to wonder: why are people distrusting of certain scientific theories, but fully trust others?

Some may like to believe that scientific skepticism is tied to one source, but there are a variety of reasons for why individuals are skeptical of scientific theories. Bastiaan Rutjens, a psychology professor at the University of Amsterdam, found in 2017 that vaccine skeptics were more likely to be religious, skeptics of genetic modification were more likely to be uneducated in science, and climate change skeptics were more likely to be politically conservative. Rutjens concluded that scientific skepticism comes in many forms and overall is not correlated to one belief system.

So what do all of the different skeptics have in common? The most basic explanation for why people doubt science lies in human intuition. Often, senses and instincts contradict the scientific facts, and it can be difficult to look past our initial judgement. For example, people who believe that the Earth is flat often cite the fact that the world looks flat, and therefore why should we doubt what we can see with our own eyes?

Even people who believe in scientific theory struggle to overcome their intuition. A study done in 2012 by Andrew Shtulman of Occidental College asked a sample of students with a basic background in science a set of true or false scientific questions. One of these questions asked the students to confirm or deny the statements: "Rocks are composed of matter" and "Air is composed of matter." He found that it took the students longer to answer scientific questions that went against intuition than scientific questions that were in line with intuition. In the previous example, although both statements are true, it took the students longer to identify the second statement accurately because it goes against intuition. Shtulman theorized that this is because "naive" theories, or our intuition, are suppressed by scientific theories, but never fully replaced.

It is often easier to believe our intuition than it is to trust the theories being thrown at us. Take evolution, for instance. It may be easier to say that all creatures were created by a god or a beam of light or on the back of a turtle, even though Darwinian evolution says otherwise. In addition, science can be wrong before it is right. This can lead people to rely on their intuition, what they already believe, to determine what is correct. And once someone believes something, it can be very difficult for them to change their mind. People are vulnerable to "confirmation bias," where they only seek and believe evidence that supports what they already believe. This perpetuates a cycle that leads people to have confidence that their perspective is correct, no matter what opponents say. As a result, individuals who have read more believe their positions more strongly, both in opposition to science and in favor of scientific theory, as Yale University psychologist Dan Kahan told National Geographic in 2015.

> "Often, senses and instincts contradict the scientific facts, and it can be difficult to look past our initial judgement."

But why do our differences in beliefs of science matter so much? Why should we care whether people believe science or intuition? Carl Krawitt knows why. His six-year-old son Rhett is in remission from leukemia, but his immune system is still weak so he can't risk being immunized, Krawitt told CBS SF Bay Area in 2015. Rhett relies on those around him to trust science and be vaccinated in order for him to be safe to attend school. However, Rhett lives in the Bay Area, and 7 percent of his classmates are not vaccinated, so his health is not guaranteed. The consequences of any one person not trusting science extend further than the effects on the individual. It's time to look past intuition and trust the facts.

Pediatrics (2015). DOI: 10.1542/peds.2014-2715
Cognition (2012). DOI: 10.1016/j.cognition.2012.04.005
Personality and Social Psychology Bulletin (2017). DOI: 10.1177/0146167217741314

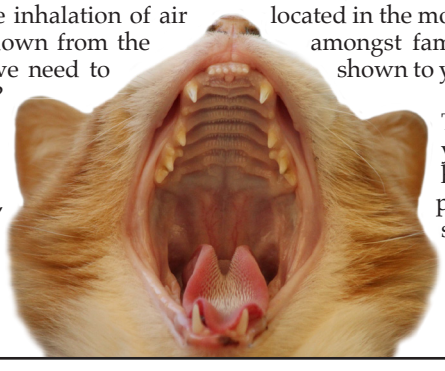
Why the long face?

NU Sci explains: yawning

BY HEATHER OFFERMANN, BEHAVIORAL NEUROSCIENCE, 2019

Yawning – we all do it, but rarely do we think about why. We yawn when we wake up, during classes, during a long night of studying; basically any time that is tiring or boring in some capacity. Through these relatable examples and cultural norms, it's a common conception that we yawn simply because we are tired. This is true, however, something must be happening biologically as a consequence of insufficient sleep that would provoke an involuntary yawn. Although there are many behaviors that trigger this reflex, scientists have proposed a few theories behind the body's need for the silent scream.

As we yawn, our jaws fully extend in a deep, long inhale. Upon completion of the yawn, our jaws close quickly as we exhale. The stretching of the jaw increases blood flow to our neck, face, and head. The intense inhalation of air forces cerebral spinal fluid and blood down from the brain and into the body. Why would we need to bring these fluids down from the brain? One theory is that our brain can "cool down". After pulling an all-nighter, the subsequent exhaustion has been shown to increase brain temperature, creating conditions not ideal for optimal brain function. Yawning allows for the circulation of cooler blood, acting as our natural radiation system.



Another theory for why we yawn is to expel excess carbon-dioxide. When we are tired, our breathing becomes shallower, lowering our oxygen intake. Yawning allows for an efficient buildup of oxygen, driving oxygen-rich blood to the brain. It has been said that nervousness or stress can also trigger yawns; a way of telling your body to keep alert in times of impaired thinking through fresh oxygenation.

It wouldn't be surprising if you have yawned while reading this article. Yawns are described as being "contagious"—reading about yawning, hearing someone yawning, and seeing someone yawning can trigger your own. This phenomenon has been related to our ability to empathize and mimic the actions of others through mirror neurons located in the motor cortex. Contagious yawning is highest amongst family members, and even dogs have been shown to yawn in response to their owners yawning.

There are many other behaviors that trigger yawning, and because of this, researchers have yet to agree on a sole biological purpose. Just remember, next time somebody yawns during your presentation, don't be offended – it's just an involuntary response to a biological change.

WHY DO I WANT TO RIP MY HAIR OUT WHEN YOU CHEW?

BY BRYNN VESSEY, BEHAVIORAL NEUROSCIENCE, 2019

Everyone is familiar with the expression of something deeply uncomfortable—like the sound of nails on a chalkboard—the horrific screeching noise that becomes all-encompassing and demands all attention. People are quick to note this sensation in cases of discomfort due to a plethora of things, but in the condition of misophonia, more than just nails on the chalkboard can evoke this feeling.

Misophonia is a disorder characterized by an intense hatred of certain sounds. It is commonly comorbid with obsessive-compulsive disorder and anxiety. Though the etiology (the causation) of the disease is not well-understood, because of its common co-occurrence with these disorders, it's thought to result due to problems in the limbic system, the autonomic nervous system, and the auditory cortex. A recent study by a British team found that the anterior insular cortex is more activated in people with misophonia than those without. They additionally found that areas of the brain responsible for long-term memory and fear were more active in sufferers. It was not surprising to find that areas implicated in emotion were more active in sufferers, as the primary response to hated stimuli is emotional. Sufferers report feeling anxious, emotional, distressed, and angry when confronting a sound.

Hatred of certain sounds alone does not constitute misophonia. The International Obsessive-Compulsive Foundation diagnoses people with misophonia if they have hypersensitivity to a sound, avoidance of sound triggers, impairments in behavior, and symptoms not better explained by a different psychiatric disorder. Common sounds that act as triggers for those with misophonia include chewing, breathing, tapping, swallowing, and patterns of speech. Because these triggers are all common occurrences, sufferers may develop routines and avoidance behaviors to attempt to limit their interactions with certain sounds. Though there is no approved or verified treatment for misophonia, because of its common occurrence with OCD, exposure and response prevention therapies are frequently used.

Though this disorder may sound like science fiction or an excuse to get upset about someone talking through favorite television shows, it is debilitating to those who suffer from it. Finding the room to have conversations and wondering aloud why people chewing makes me want to rip my hair out has also provided the space for me, as a sufferer, to learn how to talk about this disorder. When we have questions and wonders, sometimes all we need to answer them is a little bit of science.

DESIGN BY MARISSA KEESEY, ELECTRICAL ENGINEERING, 2022
PHOTOS BY PIXABAY

Another thought to keep you up at night: Why do humans need to sleep?

BY THERESA CHUNG, PHARMACY, 2024

DESIGN BY KRISTI BUI, COMPUTER SCIENCE, 2021
PHOTO BY PIXABAY

Did you know that humans spend a third of their lives sleeping? For some, sleeping is a hobby, while for others, sleep annoyingly prevents them from accomplishing so much. But everyone knows that without sleep, humans can't do anything. The body seems to malfunction when running on low hours of sleep—focus is lost, moods become sour, concentration seems impossible.

Despite its significance in our lives, the necessity of sleep still isn't completely understood. Scientists have done extensive research on the question of why humans need sleep, yet a solid answer is still lacking. Many theories have been developed, but none seem to be able to stand on their own. Rather, they all build off of each other.

Two theories that go hand in hand are the energy conservation and restoration theories.

While the body enters the period of low energy use, the nervous system produces energy to be stored. Whereas when a human is awake, she is utilizing an immense amount of this stored energy. While awake, one's body temperature and demand for calories are at their highest. The body is consuming and functioning at such a rapid pace that when it comes to the end of the day it is depleted and needs to recharge. Sleep allows humans this recharging period where energy is formed and conserved.

Almost like hibernation, this period of low energy serves as a way for the body to store reserves of energy while allowing the body to simultaneously produce new energy. The fastest way energy is formed during sleep is through synthesizing adenosine triphosphate (ATP)—an ion in our cells that both stores energy and transfers it to an energy-producing reaction—produced by glucose and glycogen molecules in the brain. Because energy is not being spent during sleep, the brain is able to conserve its glucose and ATP reserves while also synthesizing large glycogen molecules.

Sleep is also a time for reparations. Research has shown that the body experiences muscle growth, tissue repair, protein synthesis, and the release of growth hormone significantly during sleep.

The brain also repairs itself by reducing the amount of adenosine present in brain cells. Adenosine is a by-product of cell activities, produced by the neurons, that builds up while humans are awake and highly-functioning. Adenosine is believed to be one of the reasons why humans feel as though they are tired during the day. When sleeping, the brain is able to remove adenosine from cells. After these processes of energy formation and body restoration, one is able to wake up feeling refreshed and ready for another day.

A belief that has arisen recently is sleep's connection to the phenomenon of neuroplasticity. This phenomenon discusses how the brain needs sleep in order to maintain synaptic homeostasis along with learning and memory functions.

During the day, the brain is overflowed with an immense amount of new information, preventing it from being able to store all of it. Because sleep uses less energy, the brain is given time to create stable memories and connect them with already existing memories. Sleeping well regularly is necessary for a healthy memory and successful learning; repeated waking along with an ability to sleep well can actually be detrimental to one's cognitive performance.

The effects of sleep deprivation on the human body are another basis for the body's need for sleep. Lacking enough sleep results in a low level of performance in humans and a deep drowsiness during the day. However, some effects of sleep loss have been found to be even more detrimental to the human body. Sleep deprivation causes our brains to lack the energy to function in an efficient way, and the immune system is weakened. Research conducted by Drs. Luca Imeri and Mark R. Opp, published in 2009 in the journal Nature Reviews Neuroscience, found that sleep deprivation also heightens the risk of diabetes, increased obesity, cardiovascular disease, and hypertension.

For a time of low energy expenditure, sleep seems to be quite a busy time for the body. The body is able to produce and store energy and make any necessary repairs while also strengthening memory and immune functions. The reason why humans need sleep seems as simple as to why they need to eat: without it, they would not be able to live.

Nature (2005). DOI:10.1038/nature04285
Nature Reviews Neuroscience (2009). DOI:10.1038/nrn2576
Acta Physiologica (2013). DOI:10.1111/apha.12134

SENSIBLE SENSING:

The brain's ability to adapt to sensory loss

BY CAMERON YOUNG, CHEMICAL ENGINEERING, 2021

DESIGN BY KYLA VIGDOR, DESIGN, 2021

Imagine the last time you rode a roller coaster. Strapped into the car with a sense of excitement and fear as you slowly approach the top. Your brain is methodically processing all of your senses. The sight of colorful tracks contrast against a bright, blue sky. The sound of anxious riders and the car banging against the track. The smell of fresh summer air and the fairgrounds below. The feeling of the cool, metal bar holding you to your seat and the breeze against your skin. Your brain has vast processing power, able to carefully differentiate all of these senses. But, what if one of these senses was missing? How would your experience be different?

Our brains are incredibly complex, poorly understood, and sometimes seemingly magical in their functioning. Large sections are devoted to specific tasks: the auditory cortex for processing sound, olfactory bulbs for smell, and so on. For the average person, these areas of the brain function according to their pre-programmed assignments. However, not all individuals have the physical ability to comprehend every sensory input.

Blindness and deafness are the most commonly discussed disabilities of the senses, but people can experience dysfunctional sensation in any area. In fact, the lack of the ability to smell is called anosmia, the lack of the ability to taste is defined as ageusia, and somatosensory loss describes the inability to perceive touch. Sensory loss can occur in a number of ways: genetic impairment from birth, traumatic injury, or disease progression.

One might think that the areas of the brain responsible for processing senses in people with sensory impairment may remain unused. Conventional wisdom has described the brain as static, unable to change and adapt with an individual's experiences or physical limitations. However, recent findings disprove this thought and show that our brains are actually incredibly tactile and always changing.

Neuroplasticity describes the brain's ability to change and rewire itself due to one's life experiences and physical limitations. Widely accepted research has identified that areas of the brain are able to modify their function by adjusting the proportion of grey matter—areas of dense neurological stimulation—and strengthening and weakening synapses, the connections between neurons, over time. The incredible idea of neuroplasticity equates the brain to plastic, able to be molded and shaped with every new experience. As a result, no two individual brains are exactly alike, and different parts actually perform unique tasks for every person. This idea is essential for understanding how people overcome the loss of their senses.

One recent study from the University of Colorado investigated the fundamental principles of neuroplasticity to identify how the brain changes in response to hearing loss. Over 100 participants with varying degrees of deafness were monitored using electroencephalography, a device that measures cranial electrical signals, to identify brain response to stimulation of a variety of senses. The researchers were able to show that when hearing loss occurs, the area of the brain associated with processing sound is reorganized and used to comprehend the other senses. This conversion is called cross-modal cortical reorganization.

A related study from the Schepens Eye Research Institute of Massachusetts Eye and Ear investigated the strength of the other senses of blind individuals and reached similar conclusions. Using advanced MRI techniques, this study compared the brain structure of both blind and non-blind individuals, finding significant morphological, structural, and functional differences in the brains between these two groups. For example, the study noted differences in white matter connections—the major pathways in which information travels—and the occipital cortex, where vision is typically deciphered. Despite the inability to see, the study found that this area of the brain is not inactive in blind individuals. As previously described, this section is reorganized to better process not only the other senses, but memory and cognition as well. The findings of this study further support the concept of neuroplasticity, and discuss how the brain is reorganized in response to physical limitations.

Although those with a lack of sensory ability may be seen as handicapped, a growing body of evidence suggests that these individuals are certainly not at a disadvantage when it comes to brain power. The organ's uncanny ability to adapt through neuroplasticity is providing these individuals with other incredible abilities. Whether it be a heightened sense or astonishing memory, when challenged, the brain finds a way to take advantage of the opportunity. As a result, no two individuals will perceive the roller coaster experience the same way, but our brains are sure to make it meaningful for all.

Hearing Research (2017). DOI: 10.1016/j.heares.2016.08.012.
PLOS One (2017). DOI: 10.1371/journal.pone.0173064

PHOTOS BY PIXABAY

REDEFINING MUSIC:

How can quantum mechanics transform a quintessential pastime?

BY ANNABELLE MATHERS, CIVIL ENGINEERING, 2022
DESIGN BY KRISTI BUI, COMPUTER SCIENCE, 2021

From classic rock to K-pop, people have always held differing opinions on what the best kind of music is, and even what music truly is. Music is deeply interpretational, eliciting emotions and memories uniquely meaningful to each person. With this in mind, curious quantum physicists now seek to one day take the interpretational nature of music to another level. Efforts are being made to develop a hybrid piano that utilizes particle motion to produce sound, and to theorize the applications of acoustical interpretations of such particle behavior. Although mostly theoretical, further scientific parallels to musical notes, harmonies, and instrumentation pose the idea that the very structure and composition of music can be redefined using quantum properties.

One of the foundational properties of quantum physics features the inability to simultaneously observe the position and velocity of an electron. A entire realm of mathematical and physical analysis, based upon convergent probabilities of locations, seeks to understand such particle behavior. Erwin Schrödinger's popularized work on coherent superposition, with a hidden cat in situational limbo between probabilities of life and death, illustrates this variable state of existence that converges into one outcome upon visually confirming life or death. Most importantly, the feline example alludes to the idea that particle and situational outcomes may be unpredictable and multidimensional.

> "Behavioral probabilities of the atomic motion influence those of the compressing and expanding gas particles, indirectly connecting the acoustics to unique quantum patterns."

By harnessing this fluctuating particle phenomenon in an acoustical form, the resultant sound could become unique or variable to listeners, where each note exists as a convergence of probabilities. Now, the interpretational nature of music would not only be based upon personal preferences, but also on the inconsistencies in the physical outcomes of the actual notes that an individual hears. However, a significant challenge lies in creating, not solely theorizing, a device to translate quantum-particle behavior into sound itself.

Quantum Music, a Serbian project first presented in 2016 by musicians Sonja Lancar and Andrija Pavlovic, is developing a hybridized piano that seeks to translate music played on a keyboard component into particulate behavior. Acoustics from the piano become electrical signals that excite atoms within a Bose-Einstein condensate, which is characterized by atoms that are near a temperature of absolute zero. The condensate can serve as a liaison for communication between initial music notes, atoms, and the resulting behavior of those atoms. Atomic movement then creates its own acoustics by interacting with gas particles.

Sound is the compression and expansion of gaseous air at a certain frequency, which explains how the interaction between the atomic condensate and gas particles connects to musical production. Behavioral probabilities of the atomic motion influence those of the compressing and expanding gas particles, indirectly connecting the acoustics to unique quantum patterns. These ensuing sounds, which are now a translation of quantum patterns of particle oscillation and variability, can be observed by lasers and holograms, among other equipment. Finally, the new music, put through the filter of quantum mechanics, is presented through video and audio signals for the attuned listener.

The Quantum Music project, though revolutionary, is not alone in its efforts. Dr. Karl Svozil and Dr. Volkmar Putz, of the Vienna Institute of Technology, published a 2015 study elaborating on parallels between music and physics. Musical harmonies and chords occur when multiple notes are played at the same time; these notes can be compared to the multiple quantum states experienced during Schrodinger's feline superposition. This combination of states consists of atomic vibrations and frequencies that exist simultaneously, all resembling the collection of air vibrations that make up chords and harmonies. Thus, the interactions between atoms, gas particles, and acoustics of the hybrid piano can be further related.

In addition, Svozil and Putz theorize that a singular music note occurs when the quantum probabilities of the seven notes in an octave converge. White piano keys are the basis of the seven-note octave. If each note results from a specific convergence, the acoustical probability for each note could be predicted, corresponding with the various tunes that an audience might hear. Idealistically, the particular sequence of notes, and their probabilities, defines the musical quantum state. As the state, and therefore the probabilities of notes, changes with time, a melody could at last arise.

Quantum physics introduces new possibilities for music, both figuratively and literally, through hybridized pianos and theories that reveal just how in-tune music is with the surrounding world. It may even help bring together the juxtaposed worlds of musical genres, one rockin' and poppin' atom at a time.

Soft Computations (2017). DOI: 10.1007/s00500-015-1835-x

BLACK HOLES DEBUNKED

BY KRISTINA KLOSOWSKI, BEHAVIORAL NEUROSCIENCE, 2021 PHOTO BY MUHAMMAD ELARBI

When you hear the term "black hole," you likely picture just that—a gap in the "fabric of space," as Neil DeGrasse Tyson, a well-known American astrophysicist and science communicator would put it. This, however, is a misconception. Black holes are extremely dense concentrations of matter, fitting the mass of two to three suns into an area the size of a city. Black holes are created when massive stars at the end of their life cycles implode inwards on themselves.

They have long been shrouded in mystery, and astrophysicists, philosophers, and science fiction authors alike have raised questions that are so far unanswerable. What happens to you if you were to fall into one? Where do they lead to, if anywhere? Although we lack definitive answers, we do know enough to debunk a few other misconceptions.

Despite having a massive gravitational field, black holes are not giant vacuums—they do not simply suck up everything around them. In fact, scientists say that if an equally massive black hole were to be plopped down where the sun is now, the planets would likely continue in their orbit. Black holes can even orbit each other. Researchers at the University of New Mexico, who have been observing two black holes in a distant galaxy located millions of light-years from Earth, have finally been able to provide evidence of this by painstakingly plotting their trajectories. It is also hypothesized that black holes often end up in each other's' orbits as a result of two galaxies merging.

And despite how massive they are, black holes do not exist infinitely. Over an extensive period of time, they will eventually "evaporate" and disappear. Black holes emit trillions the amount of energy emitted by some stars. Theoretically, since matter and energy only change form and cannot be created or destroyed, it follows that black holes over time convert their enormous amount of densely-packed matter into energy, which is then given off into space.
And this is just the tip of the iceberg—much remains to be learned and observed about these obscure entities that exist in our universe.

Science of soap bubbles

BY ISABEL KAIN, PHYSICS, 2021

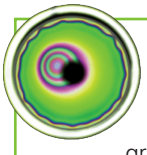
Bubbles are the subject of fascinations for young children and legendary physicists alike; though pretty to observe, they also offer intriguing lessons in fluid dynamics. Looking closely at the surface of a soap bubble, a shimmering, iridescent surface swirling with activity can be observed. These mesmerizing patterns are due to the Marangoni effect.

This phenomenon comes into play when there is a gradient of surface tension along the interface between two phases of matter—in this case, the boundary between the liquid bubble and the gas filling it. This gradient means that the surface tension is greater at some parts of the surface than at others. As a result, molecules called surfactants, which reduce local surface tension, are tugged towards regions of higher surface tension. This in turn changes the surface tension gradient. The colors on the bubble come from these changes in the thickness of the film, so this surface flow creates the dizzying rainbows that make bubbles so amazing.

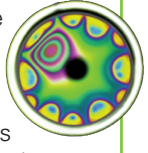
But is it possible to halt those swirling Marangoni flows in their tracks? Pursuing this question originally asked by a high school intern, a team of researchers at Stanford created a tiny air bubble only one millimeter wide just beneath the surface of a bath of surfactants. The bubble was pushed upwards one tiny step at a time so that it poked above the surface of the bath. Each upward push introduced a new surface tension gradient to the exposed bubble, triggering new Marangoni flows along the outer rim of the bubble. Each new wave of Marangoni flows trapped the previous one, eventually creating a stable surface composed of layers of an inherently chaotic yet beautiful phenomenon.

"You almost expect that things that are mundane—day-to-day objects, simple things—are all figured out. You take it for granted," said lead author Saad Bhamla in an interview with Stanford News. But this experiment proves otherwise: something as simple and whimsical as bubbles can blow open fascinating avenues of scientific inquiry. whimsical as bubbles can blow open fascinating avenues of scientific inquiry.

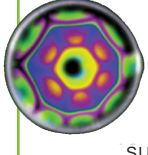
Images: (Top two) Single Marangoni flows decay to chaos. (Bottom two) Multiple Marangoni flxows are layered on the bubble surface.



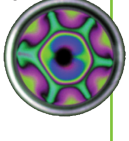
The surface of a soap bubble is not perfectly uniform – there is a gradient of surface tension along the film, meaning there are regions of high and low surface tension.



Liquid with a high surface tension pulls more strongly on the surrounding liquid than one with a low surface tension, so this gradient causes molecules called surfactants to flow away from low surface tension regions towards high-tension regions.



Surfactants lower local surface tension. As they flow between different regions of the bubble's surface, they change the surface tension gradient even further, creating complex swirling flows.



Variations in thickness of the film are also introduced by surfactant flow, creating the hypnotizing kaleidoscopic colors that make bubbles so fascinating!

DESIGN BY LILLIE HOFFART, ENVIRONMENTAL SCIENCE, 2022
PHOTOS BY BHALMA, FULLER

Physical Review Fluids (2016). DOI: 10.1103/PhysRevFluids.1.050506

Fat stacks of thin materials:

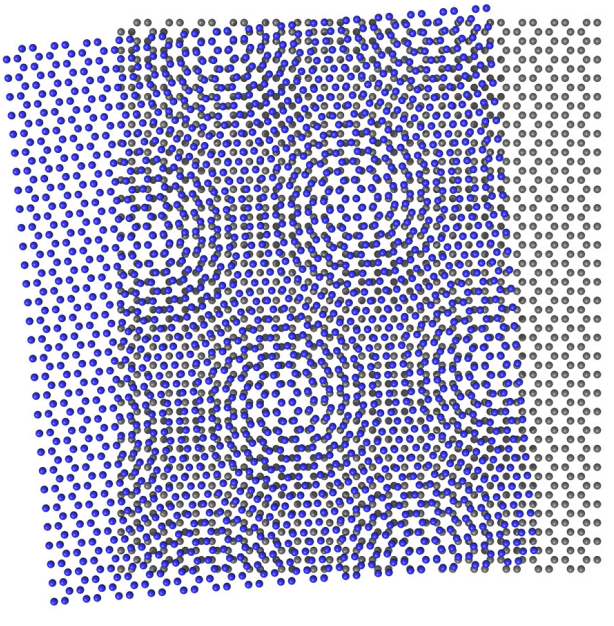
The rich phenomena of twisted 2D layers

WRITTEN AND DESIGNED BY JENNIFER GARLAND, APPLIED PHYSICS & MATHEMATICS, 2021

For most of the history of materials science, layered crystal growth has been limited to the particular arrangements in which atoms tend to align. Professor Pablo Jarillo-Herrero, an experimental condensed matter physicist at MIT, compares layered crystal growth to stacking Legos. Each layer of atoms had to be stuck on the next with zero degrees rotation. However, at the 2018 American Physical Society (APS) March Meeting, Jarillo-Herrero and his group presented a technique to control the angle between two graphene sheets, creating what is called twisted bilayer graphene. Interesting phenomena arose with this unprecedented tunability in layering materials, including most notably, superconductivity, the complete lack of electrical resistance, at a "magic angle" of about 1.1 degrees.

Since then, the physics community has focused on developing theories and experiments in a new field known as "electron quantum metamaterials." It covers materials that do not occur in nature and have been engineered to obtain emergent electronic properties. Van der Waals heterostructures, stacks of atomically-thin materials held together by electrical attractions between molecules, such as twisted bilayer graphene, are just one subset of examples.

"The thing which is interesting and relevant and has attracted a lot of attention is the fact that we can play with this twist angle degree of freedom, so another word that people use to refer to this field is called 'twistronics' - twist angle electronics," said Jarillo-Herrero. "If you rotate by an angle, you form a moiré pattern, a super-periodic structure." Moiré patterns occur when two geometric patterns are overlaid and offset. When the hexagonal patterns in graphene are offset by a small angle, the two sheets interact more strongly, giving the system new properties. A single sheet of graphene is the best regular conductor we know of, but depending on the twist between two sheets and their charge, the combination can become either an insulator or a superconductor.



A team of researchers led by Professor Matthew Yankowitz at Columbia University showed that applying pressure to two stacked graphene sheets allows electrons to move between layers more easily. For different pressures, different twist angles cause superconductivity. The experiments at MIT were conducted at ambient pressure, and this evidence that the pressure is a relevant variable confirmed that the properties are dependent on interlayer coupling.

> "When the hexagonal patterns in graphene are offset by a small angle, the two sheets interact more strongly, giving the system new properties."

Much is still to be understood, and Jarillo-Herrero describes a few categories of exploration. "One is to further study the properties of graphene at the magic angle. Many of the experiments that we and many other people are doing are trying to better understand the physics of this particular system," he said.

Another is experimenting with more than two layers. A year after the initial announcement, at the 2019 APS March Meeting, new research was presented on twisted bilayer-bilayer graphene: two bilayers, each stacked with zero angle between them, that are then rotated with respect to one another. At particular angles in this system, interesting correlated physics arises at a larger range of twist angles, improving upon the 0.2 degree range of twisted bilayer graphene. The ability to stack multiple layers introduces many degrees of freedom, as each can be twisted with respect to the others. Theorists are currently investigating these combinations in hopes of creating a more robust kind of superconductivity.

Additionally, the investigations are not just limited to graphene. Any other 2D material, such as transition metal dichalcogenides, can be manipulated in the same way, and superconductivity has also arisen in these systems at certain twist angles. Due to the vast array of customizable features and potential phenomena, van der Waals heterostructures have become an influential gateway to new nanotechnology for electricity transmission and information processing.

"Each 2D material brings a new or unique flavor," said Jarillo-Herrero. "The whole community is playing with 2D materials, twisting them, and seeing what happens, and, as you can imagine, the possibilities are infinite."

Nature (2018). DOI: 10.1038/nature26160
Science (2019). DOI: 10.1126/science.aav1910

PHOTO BY NATIONAL INSTITUTE OF STANDARDS AND TECHNOLOGY

INSIDE THE MIND OF A TWO-YEAR-OLD:
COGNITIVE DEVELOPMENT OF CURIOUS TODDLERS

BY SAGE WESENBERG, BIOLOGY & JOURNALISM, 2019

DESIGN BY MARISSA KEESEY, ELECTRICAL ENGINEERING, 2022

My two-year-old cousin knows all the words to his favorite Beatles songs, can distinguish a seaplane from a commercial airplane high up in the sky, and knows how to corral his family's chickens back into their coop.

Every time I get to play with him or talk to him during a car ride, it's amazing to see the observations he makes and hear what's on his mind. It always makes me wonder: what's going on inside his toddler brain?

The first several years of life are crucial for brain development—over a million new neural connections are formed every second, and the brain quadruples in size by age six. From developing the ability to differentiate sounds like their native language, to interpreting and recognizing faces, many important sensory cues begin to develop before the age of one. These are later complemented by early language skills and more complex cognitive functions.

Much of what we understand about early cognitive development can be credited to Swiss psychologist Jean Piaget. His 1936 Theory of Cognitive Development laid the groundwork for understanding how a child mentally understands the world and how early education can supplement this process. The theory focused on early child development and the use of basic mental structures for all future learning and knowledge.

Built with three components, Piaget's Cognitive Theory aims to explain the mechanisms behind how infants and children grow to possess reasoning skills. First, Piaget identified schemas—linked mental representations of the world that function as the building blocks of knowledge. By constantly developing new schema, we can create a system to organize information and relate it to different pieces of the world. As a child develops, their schema increase and become more complex, improving their perception of the world and creating the tools needed to understand or react to a situation.

Next, Piaget focused on the idea that intellectual growth requires both assimilation and accommodation for a child to adapt to the world. Assimilating uses schema to deal with a new situation, whereas accommodation occurs when existing schema doesn't work in a situation and needs to be changed. Both of these pieces help develop acquired schema to a point of equilibrium where they can apply to most situations.

Finally, Piaget outlined four stages of cognitive development. Starting at the sensorimotor stage—from birth to age two—infants are able to evolve from using reflexes like sucking to learning intentional movements like reaching for a bottle. They also learn object permanence, understanding that objects exist even if hidden, by building upon the schema they have for that object.

From ages two to seven, as children move into the pre-operational stage, they become egocentric and are unable to understand any viewpoint other than their own. This is where a lot of pretend play starts to occur, as their brain starts to develop symbolism and imagination.

In the concrete operational stage from ages 7–11, children experience a huge turning point in their cognitive development. Here, they begin to develop logical thought and preliminary problem-solving skills.

Another important concept gained here is conservation—understanding that even if the appearance of something changes, its quantity is still the same. This is often exemplified with a glass of milk that gets poured into a taller, skinnier glass. Before this stage, a child would think that there was more milk in the skinny glass. However, once they're able to develop conservation, a child understands that it's the same amount of milk that was in both glasses.

Piaget's last stage of cognitive development is the formal operational stage from 11–16 years and into adulthood. This is where children begin to develop abstract thoughts and use complex problem-solving in their day-to-day lives.

Many adults don't realize how cognizant toddlers are of their surroundings. Even infants understand that a person's behavior is correlated with their emotions. Reading these social cues helps an infant to make sense of the world, store those schema, and use them to inform their future decisions and observations.

For my cousin, I can see his growing use of symbolism and imagination and I can only wonder what story he's telling as he pushes his trains around their track. I've witnessed him applying his egocentric views to those around him—if he's eating ice cream, then I too, should be eating ice cream. And I can continue to watch his motor skills grow as he feeds himself, tells me about school or sings a song, and runs after his chickens.

PHOTO BY GREG HREN PHOTOGRAPHY

Proceedings of the National Academy of Sciences (2012). DOI: 10.1073/pnas.1114783109

Beauty and the brain:

The neuroscience behind appreciating art

BY KAELEN ENCARNCACION, BIOLOGY & ENGLISH, 2021

DESIGN BY MARISSA KEESEY, ELECTRICAL ENGINEERING, 2022

You're walking through an exhibit in the Museum of Fine Arts. Surrounded by pieces of immeasurable value, you feel inexplicably moved. Is this vague feeling merely an emotional response to something you find aesthetically pleasing, or could this be a result of something hard-wired into your brain?

This idea is what lead to the emergence of "neuroaesthetics," a relatively recent scientific discipline concerned with bringing objectivity into the study of art, music, or anything that gives rise to aesthetic judgement. Researchers in this field have sought to determine if there is a neurological basis to artistic techniques and styles, as well as provide some insight into why we find particular things "beautiful."

As the light and air-inspired impressionism of the 19th century led into the wild spontaneity of abstract expressionism mid-20th century, many critics denounced modern art, claiming that its lack of clear interpretability reflects its creators' lack of skill compared to the artists who came before. Nevertheless, the masses still flock to the Museum of Modern Arts to catch a glimpse of a Rothko or Pollock. Why so?

Neuroaesthetics would hypothesize that the human brain can pick up on the little complexities that underlie abstract paintings, showing that these artists may have made specific artistic choices that subconsciously appeal to our brain's visual system. In one study from the University of Ontario, researchers rearranged the position of objects within a series of paintings and set them side-by-side with the original compositions without telling participants which is which. They found that nearly everyone preferred the original painting. They also found that viewing the manipulated pieces led to reduced activity in brain regions typically associated with interpretation and meaning, suggesting that we subconsciously take note of the meticulous arrangements and intentions behind the paintings, even if they appear indecipherable.

So, is this "art intuition" a special ability built into our brain's wiring? Neuroaesthetics has adopted the notion from art philosophy that our perception of beauty comes from a specialized pathway distinct from that of when we look at an ordinary object. In other words, viewing a Monet painting would be cognitively different from looking at a burrito. As such, neuroaesthetic research has also sought to determine brain regions specifically involved in the aesthetic appraisal of art.

Researchers from McMaster University and York University in Ontario applied quantitative meta-analysis to 93 human neuroimaging studies involving vision, hearing, taste, and smell in order to determine which brain regions are involved in aesthetic appraisal. Surprisingly, the results showed that the brain region most prominent in aesthetic appraisal was the anterior insula. While it has been associated with a variety of functions, the insular cortex is typically attributed to providing emotionally-relevant context to physiological experiences. In other words, it attaches emotions to bodily states, such as discomfort with pain or excitement with increased heart rate. The anterior portion of the insular cortex, specifically, has been associated with negative emotions, such as disgust, anger, and sadness. It seems counterintuitive that such a region would be crucial in appreciating art.

However, the anterior insula is also part of the brain's "interoceptive system," a group of regions that assess the state of our internal organs. Other parts of the brain, such as the orbitofrontal cortex, then respond to sensory stimuli in the external environment. This leads to the phenomena of our emotional state depending on our physiological state, such as how a burrito may elicit positive emotions when hungry, but turn to disgust when sick. Therefore, regions like the anterior insula and orbitofrontal cortex become activated both when sensing pleasant sights and smells as well as being awestruck by Renaissance paintings or Beethoven concertos.

The researchers suggested that the aesthetic appraisal system in the brain originally evolved to evaluate objects of biological importance such as food or attractive mates, and later adapted to artworks and music to satisfy social needs. So technically, a Monet is just as beautiful to your brain as a burrito. Based on this, it would be unlikely that there's a specialized system for appreciating beauty alone, but rather a more generalized system that determines how "pleasing" an object is.

While neuroaesthetics is a relatively new scientific field, a multitude of studies have come out to elucidate why we cherish art so much. In a way, it shows that art and science may not actually be that different after all: we study the complex patterns in our environment or within frames, seeking a greater understanding and appreciation of the world around us.

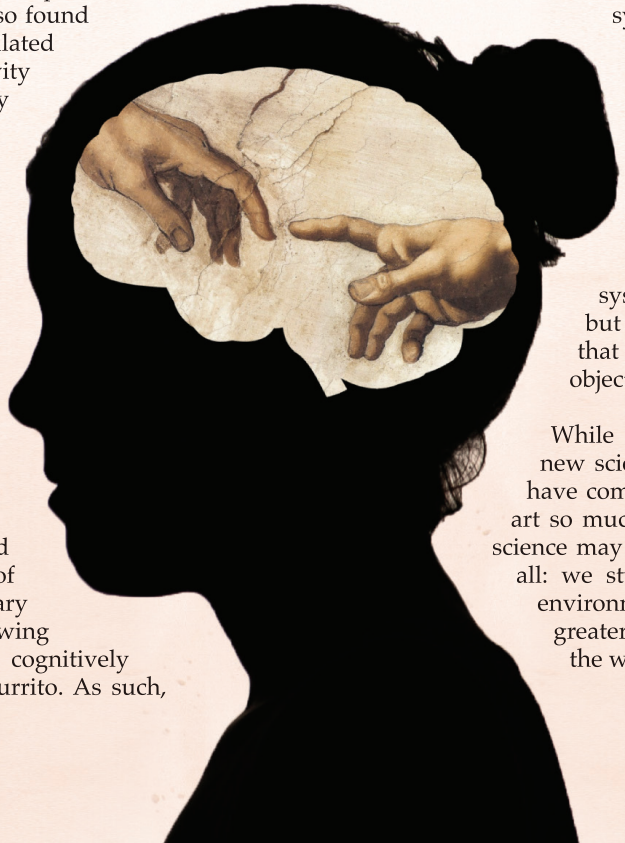


PHOTO BY FLICKR

Neuroimage (2011). DOI: 10.1016/j.neuroimage.2011.06.012.
NeuroReport (2003). DOI: 10.1097/01.wnr.0000118723.38067.d6

A dream is a wish your heart makes ... or is it?

BY JUNIANNA BORGIA, BIOLOGY, 2022

DESIGN BY KATIE GREEN, BIOENGINEERING, 2021

Dreaming is a phenomenon that almost everyone experiences. Some find dreams to be inspirational and informative, while others may think that they are just something that happens once you close your eyes. Whatever one's opinion on dreams is, there's no denying that these episodes of subconscious activity have been the subject of fascination for centuries. In ancient societies, dreams were viewed as visions from divine entities and some civilizations even used the dreams of kings and noblemen to create laws. Even after millennia of documenting, interpreting, and acting on dreams, the question of why we dream is still a mystery.

Sleep occurs in cycles that have different stages. These cycles include stage one sleep, with muscle relaxation and slow eye movements; stage two, with body temperature decreasing and the brain preparing for deeper sleep; stage three, with slow waves in the brain for the most restorative sleep and rapid eye movement (REM) sleep. In REM sleep, muscles become paralyzed and brain activity is higher than in stage two and three, indicating that the person is dreaming. Even though the physical nature of a body in REM is much different than in wakefulness, the brain activity in these two levels of consciousness can be surprisingly similar. A PET scan done in a study published in *Trends in Cognitive Science* in 2010 revealed that brain metabolism, the use of glucose as energy, is "comparable between wakefulness and REM sleep," according to study authors Nir and Tononi.

While physical assessments may show similar brain activities for certain aspects of a wakeful brain and a brain in REM, there are intriguing differences in the two states of consciousness. Reflective thought in dreams can be greatly decreased compared to the real world. This means that in a dream scenario, bizarre occurrences like breathing underwater may appear ordinary and not cause much alarm. When a person is dreaming, the prefrontal cortex has been partially deactivated, which could account for this lack of reflective thought. Emotions such as joy, excitement, anger, and fear can be heightened in dreams. The heightened emotion in dreams has historically been interpreted to suggest that "dream narratives originate in perceived threats or conflicts," as shown by Nir and Tononi. REM sleep shows activation of the amygdala and the insula, which are both structures in the brain that control emotion during wakefulness.

There has been much research done about the physical nature of the brain while it is dreaming, but there is still speculation as to why dreaming is such a common occurrence. One theory is that dreaming can serve to aid in memory processing. During REM, memories that have been stored in the short-term may be transferred to long-term memory through the process of dreaming in mechanisms not yet understood. Another theory is that the brain could possibly be exploring conflicting or stressful situations. The dreamer often lacks self-awareness, so the brain can pick apart the situation at hand with a different viewpoint. Dreaming can also serve an evolutionary purpose if it allows the brain to rehearse different courses of action in a threatening scenario. A study was conducted by the University of Turku in 2005 to test this evolutionary theory. In the study, the dream quantity and content from children who faced traumatizing situations such as war and poverty were compared with those who lived a relatively safe and stable life. The results of this comparison were that those children who were traumatized had more dreams overall, and a higher portion of their dreams tended to be focused on some sort of threat the children faced when awake. This could indicate that dreams do indeed serve as some form of "preparation" for conflicts that may be faced in real life and giving the dreamer insight on how to deal with such threats successfully.

Dreams are gateways into the subconscious that can make us laugh, cry, or think about aspects of life through a different lens. The complexity of these scenes has fascinated man for most of human history, and even today the reason of why we dream remains a captivating mystery.

Consciousness Cognition (2005). DOI:10.1016/S1053-8100(03)00019-9
Trends in Cognitive Science (2010). DOI: 10.1016/j.tics.2009.12.001

YOU CAN DO ANYTHING:

The reality of engrams and imagination

BY MICHAEL ISKOLS, BEHAVIORAL NEUROSCIENCE, 2022

DESIGN BY KATIE GREEN, BIOENGINEERING, 2021

Imagine a horse wearing a red bowtie with a pineapple on its head.

While you (unfortunately) have never seen such a horse, you're able to picture it effortlessly. Dr. Andrey Vyshedskiy of Boston University argues that prior observances of a horse, the color red, a bowtie, and a pineapple enable their aggregation into the imaginary. This transition from memory to imagery differentiates our virtual reality from actuality, in which external stimuli, like sound and light waves, are received and interpreted using memory processes.

Each recalled component of the picture, whether the horse or the red bowtie, is encoded by a unique group of coordinated neurons in the brain's frontal lobe—the area responsible for higher-level processing. Concurrent activation of the separate neuronal groups combines these images and initiates the creation of a novel object, a process that Vyshedskiy refers to as *mental synthesis*. Individual neuronal ensembles, often called *engrams*, exist to represent not only these seemingly menial memories of characteristics but also complex emotional content.

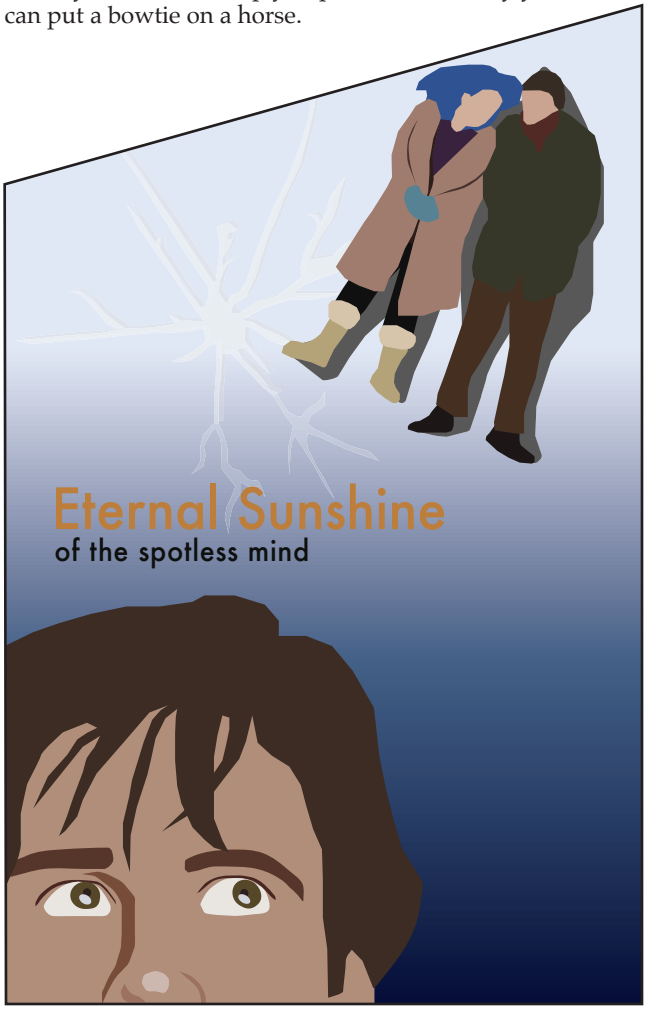
Eternal Sunshine of the Spotless Mind, the 2004 Sci-Fi/Romance movie, depicts a seemingly outlandish procedure that targets and removes a man's (played by Jim Carrey) recollection of his ex-girlfriend following a painful breakup. In reality, Dr. Susumu Tonegawa works at MIT to manipulate engram activity during fear conditioning to alter memories—bringing Jim Carrey's bittersweet ignorance closer to reality.

When mice are trained to fear environment A, a box with a shocking floor, Tonegawa captures the group of neurons active in the hippocampus, the brain's memory center, with a light-sensitive protein. In environment B, of which the mice are not afraid, Tonegawa turns on a light-fiber and ultimately the emotional memory of environment A, eliciting a fear response.

In this *optogenetic* technique, he demonstrates how engram activation is *sufficient* in activating fear memory, just as it might have enabled you to picture the horse in a bowtie with a pineapple. Tonegawa's colleagues were also able to selectively remove a fear association using similar engram-targeting methods, so why can't the same be done with Carrey's former love?

With neuronal groups in the frontal lobe building mental images from memory and others in the hippocampus storing those memories, the sensory cortex is responsible for representing the body in context. What if, at the meeting of two rooftops, you were asked to leap across? You will likely consider your outcome, simulating the jump in your mind before deciding if you would like to succumb to peer pressure. According to Dr. Michael Brecht of Humboldt University, this *avatar* resides in your sensory cortex. As new sensory information arrives, the cortex is constantly updating this mental simulation, storing stereotyped movements as memories, and initiating planned actions. In this situation, the engrams encoding the perceived gap distance, your possible jump length, and your body position would coactivate, enabling you to *see* your avatar's leap across the gap.

What if you were asked to imagine yourself riding that horse? Mental synthesis between your frontal, memory, and sensory centers will help you picture it, but only you can put a bowtie on a horse.



Neuron (2017). DOI: 10.1016/j.neuron.2017.05.018.
Nature (2014). DOI: 10.1038/nature11028

Monkeying around

BY SARA GANNON, BEHAVIORAL NEUROSCIENCE, 2021 DESIGN BY JARED BRAUSER, MECHANICAL ENGINEERING, 2023

The thought of a monkey playing a first person shooter video game seems far-fetched, but based on current research, it may not really be such an outlandish proposition.

Evolutionary history aside, monkeys are probably the easiest animal to anthropomorphize: not only do they look like us, but because they act a bit like us as well. Scientists across the world utilize nonhuman primates for research due to all of the similarities that are shared between the species. Namely, intelligence: chimpanzees are capable of being trained to navigate virtual mazes, and, with practice, can develop navigation and problem solving skills that rival humans' abilities. At the Language Research Center at Georgia State University, four adult chimpanzees named Lana, Mercury, Panzee, and Sherman confirmed just that.

In a virtual maze task, Dr. Francine Dolins and her team compared the skill-based results of chimpanzees to those of human children and adults. Each group was tested on its ability to find the shortest, most efficient route from the starting to the goal position in the maze. The study discovered that across almost all maze variations, chimpanzees consistently performed as well as three to six-year-old children. One all-star in particular, Panzee—a 22 year old monkey—actually outperformed those children by inventing shorter, more efficient routes than they did to get through the maze.

Moreover, a study conducted in Kyoto, Japan, found that primates are actually capable of perceiving themselves as a distinct entity in a video game. Drs. Takaaki Kaneko and Masaki Tomonaga determined that monkeys are able to perceive their own role in a video game and can accurately identify the object or character that they are playing.

This discovery was made by training chimpanzees to play a simple game: moving a ball with a cursor. After they learned the basic game, the researchers introduced a second cursor. This new cursor's movement on the screen was determined based on previously collected data from the same monkey. That is, the scientists succeeded in giving the monkey a distracting cursor, capable of interacting with the ball, that could potentially be confused with the cursor the monkey was controlling himself. As the game ran, if one of the cursors successfully moved the ball to the goal position, the game ended. At this point, the monkey was asked to choose which cursor he believed was his by having him physically point it out on the screen. The researchers discovered that primates were extremely successful at identifying their own cursor, achieving accuracy rates of up to 99 percent.

The discovery of self-awareness in primates has actually made it possible for other researchers, like Dr. Peter Ifft and his team, to use nonhuman primates to develop devices for humans, such as brain machine interfaces (BMIs). The term "BMI" covers a wide scope of technology, but generally implies a communication pathway between the brain and an external device.

At the Center for Neuroengineering at Duke University, Ifft is studying a way to create movement in an artificial arm prosthesis based solely on brain activity. In the preliminary steps of development, the team has used monkeys to look at whether or not this type of BMI could be learned by primates, and they have had great success so far.

One of their primate subjects, Monkey C, began his training by using a joystick to manipulate an artificial "arm" on a screen in front of him. The video setup was relatively simple: a target on a screen and a virtual arm that could be manipulated (via the joystick) such that it moved to touch a target. After he mastered that task, the next step was to have the monkey use the joystick while researchers recorded his brain activity via chronically implanted multi-electrode arrays. This setup made it possible to decode the signals emitted during movement and determine connections between groups of neurons and physical actions.

Scientists then presented Monkey C with both virtual arms, but no joystick. With his own arms slightly restrained, the brain activity that occurred during attempted movements could be computed in real-time such that his virtual arms completed the task. The most noteworthy discovery of this study was that after only 15 days of practicing with virtual arms controlled solely by brain activity, the monkey reached a skill level of which the researchers deemed proficient.

Now, it's clear that monkeys have a general intelligence that rivals that of humans—or, at the very least, children. From playing video games to developing neural prostheses, it's safe to assume that we still have a lot to learn from our fellow primates.

American Journal of Primatology (2014). DOI: 10.1002/ajp.22252
Proceedings of the Royal Society B: Biological Sciences (2011). DOI: 10.1098/rspb.2011.0611
Science Translational Medicine (2013). DOI: 10.1126/scitranslmed.3006159

PHOTOS BY PIXABAY AND GOOGLE

The complexity of consciousness

What defines cognition on a neurological level?

BY MELISSA FRANCO, BIOLOGY, 2020

The concept of consciousness has eluded humanity since the days of Greek philosophers. Many have sought to describe, define, and even recreate what we call consciousness, but each attempt seems to fall short in one aspect or another. Common philosophical approaches have been taken by psychologists and mathematicians, but recently, a group of researchers based in France have taken a more literal approach to the issue. They aimed to define consciousness by the neurological processes that differ between conscious and unconscious individuals.

Their experimental design was simple. They utilized fMRI, a brain imaging technique that allows for real time mapping activity of neurological pathways on 169 individuals of varying levels of consciousness. About one-third of the study's participants were healthy individuals acting as controls. The rest were composed of individuals who suffered from illnesses that impact their cognition, and ranged from being unresponsive to minimally conscious, as defined by the researchers. A subsection of these participants were in a medically induced state of reduced consciousness by anesthesia. This assortment allowed the researchers to narrow down differences in cognition between the groups and identify factors that truly relate to consciousness.

The brain imaging results were collected and processed to normalize and analyze patterns of neurological activity. Scientists noticed that the patterns of activation in healthy brains significantly and consistently differed from those of less conscious participants. These variances allowed the researchers to classify four types of brain patterns. Type 1, present in mostly healthy individuals, showed a much higher rate of coordination within differing brain components, indicating that this "communication" between separate areas of the brain is a crucial element of consciousness. These patterns were decreasingly present in each following pattern type, showing reproducibility in the trend and further reinforcing its relevance to consciousness, essentially showing a positive correlation between consciousness and complexity of brain function.

This incredible research was a huge advance in attempting to understand consciousness at a physical level. It will likely have significant impacts on medical treatment of similar diseases and development of medicines that can target or enhance inter-neuronal functioning. It is even plausible that this new research's ramifications will reach into the realm of machine learning, as a development for neural networks, which are already based on the brain's functioning. These impactful research and treatments blossom from the same challenge that has stumped philosophers for thousands of years; this time, potentially addressed by modern neural mapping.

Science Advances (2019). DOI: 10.1126/sciadv.aat7603

THE CURIOUS POSSIBILITY OF SILICON-BASED LIFE

BY CONNOR WALRATH, MECHANICAL ENGINEERING & PHYSICS, 2022

Life on Earth is composed of organic molecules formed by chains of carbon atoms. Scientists have long wondered, "why carbon?" Why not a similar element, like silicon, to serve as the building block of all life?

Carbon and silicon both have the ability to form bonds to four atoms simultaneously, making them ideal to be the backbone of complex, molecular structures. Silicon is roughly 150 times more abundant in Earth's crust than carbon, making up about thirty percent of Earth's crust by mass. The closest nature has come to producing an organism made up of purely organosilicon molecules are phytoliths, tiny particles of silicon dioxide found in grasses, and diatoms, a type of photosynthetic algae that incorporate silicon dioxide into their skeletons.

No known organism consists only of organosilicon molecules, but synthetic chemistry has allowed us to study various methods to bond silicon and carbon in ways not found in nature.

In 2016, researchers at the California Institute of Technology led by Frances Arnold optimized an enzyme to produce organosilicon molecules through directed evolution. Directed evolution is performed across many iterations, enhancing one enzyme in several different ways and testing each result for desirable traits. The result with the most desirable traits is then enhanced further. This method is similar to the way breeders select race horses for future generations.

The team at CalTech performed three rounds of directed evolution before arriving at an enzyme that catalyzed the formation of silicon-carbon bonds 15 times faster than before directed evolution. The success was found in cytochrome c, an enzyme usually found in Icelandic hot springs. This enzyme was highly enantioselective, meaning it became very picky about the orientation of molecules, which resulted in the enzyme producing more enantiopure (properly oriented) organosilicon molecules. This meant less unwanted byproduct of the reaction, and greater efficiency overall.

Arnold posits that future research could involve giving an organism the capability to create organosilicon molecules via cytochrome c. This research would explore why we don't come across that phenomenon in the natural world. It seems curious that nature has not experimented more with silicon. As Arnold said after the research was published, "Nature could have done this herself if she cared to."

Science (2016). DOI: 10.1126/science.aah6219.

PHOTOS BY WIKIMEDIA COMMONS

DESIGN BY KYLA VIGDOR, DESIGN, 2021

GASDERMIN AND THE ILLUSIVE INFLAMMASOME

BY HUGH SHIRLEY, BIOCHEMISTRY, 2019

DESIGN BY TRAM ANH NGUYEN, BIOLOGY, 2022

There's more than one way that a cell can kill itself. The standard version of cell suicide, apoptosis, is happening constantly within our bodies. When a cell detects damage, harmful mutations, or infection, apoptosis is often the response. This process has evolved to be clean, quiet, and effective, so that surrounding cells are not damaged while the immune system cleans up the apoptotic cell's debris. Apoptosis refers to programmed cell suicide and has been at the center of countless cancer, aging, and development studies, but cells can undergo more than just apoptosis in response to damage. Enter pyroptosis and the Gasdermin protein family.

Pyroptosis was coined in 2001 from the Greek "pyro" for fire and "ptosis" for falling. Inflammation caused by bacterial infections has been studied as part of natural immune response for centuries. In 2001, Dr. Brad Cookson first described pyroptosis as a cellular mechanism behind that response. For over a decade, it was not well understood how pyroptosis occurred in cells. It was known that infected immune cells, such as macrophages, would develop relatively large pores in their membrane, flooding the extracellular environment with the components of their cytoplasm, like a deflating balloon. The crucial piece of missing information was how the large pores in the membrane were made in the first place. Many of the early papers on pyroptosis left a big question mark for that part of the pathway.

> "Pyroptosis, while at first glance might seem like a big negative for host cells, can provide several immunological advantages."

The pyroptotic pathway involves the formation of a protein complex called the inflammasome. The aptly named assembly is built in response to signals from intracellular bacteria, viruses, or cell damage. One goal of the inflammasome is to activate caspase-1. Caspase-1 is the protein that was long thought to be the cause of the membrane pores associated with pyroptosis, but a recent paper revealed that that wasn't the case. Gasdermin, a family of proteins linked with pyroptosis, was discovered as the actual pore forming protein in 2017 by Dr. Ana Morandini. Caspase-1 is responsible only for cleaving away parts of the inactive gasdermin protein, allowing the active portion to carry out its pyroptotic mission. Caspase-1 also activates interleukin-1β. Active IL-1β can flood through the holes created by gasdermin into the extracellular environment and help stimulate further inflammation by recruiting more immune system cells to the area.

Gasdermin has a lot of potential as an antibiotic. The ability to punch holes into membranes is a highly coveted biological advantage that many organisms exploit through multiple strategies. Studies have shown that active gasdermin spontaneously forms pores in lipid bilayers in solution—meaning that once caspase-1 cleaves gasdermin into its active form, there's nothing stopping its pyroptotic activity. One remaining question is how gasdermin gets through a prokaryotic outer peptidoglycan wall so that it can access the membrane. While the pharmaceutical applications are still a big unknown for gasdermin, we do know more than previously about what's happening *in vivo* during pyroptosis and why it occurs in the first place.

Pyroptosis, while at first glance might seem like a big negative for host cells, can provide several immunological advantages. By flooding the extracellular environment with toxic metabolic compounds from the pyroptotic cell, the body can fight off bacteria that's growing in that extracellular space. The recruitment of additional immune system cells to the area through the release of signal molecules like IL-1β further strengthens the body's fight against pathogens. Pyroptosis, and therefore gasdermin, can still cause significant damage to the host. Uncontrolled pyroptosis is linked with septic shock. Septic shock is a life threatening stage of sepsis, or infection of the blood. Inflammation and sepsis go hand in hand, so pyroptotic cells that release inflammation inducing signaling molecules in response to a bacterial infection could be the reason behind septic shock.

The relatively new molecular world of pyroptosis is an ongoing field of study. Gasdermin provides the missing link between what induces pyroptosis and the physiological signs that we observe. Now, with a more complete picture, researchers can study how we can take advantage of gasdermin as an antibiotic and as a player in septic shock. Who knew there was so much more to cell suicide!

Biomedical Journal (2017) DOI: 10.1016/j.bj.2017.10.002
Trends in Biochemical Sciences (2017) DOI: 10.1016/j.tibs.2016.10.004
Trends in Microbiology (2001) DOI:10.1016/S0966-842X(00)01936-3

GRAPHIC BY GOOGLE CREATIVE COMMONS

THE FUTURE OF LIFE ON MARS

HOW HUMANS COULD CALL THE RED PLANET HOME

BY ZACK LAPOINTE, MECHANICAL ENGINEERING, 2021

DESIGN BY TRAM ANH NGUYEN, BIOLOGY, 2022

In 2001, technology entrepreneur and founder of SpaceX, Elon Musk, came up with an idea to send an experimental greenhouse into space. His goal was to land it on Mars and grow plants. Musk's announcement of his "Mars Oasis" project, as he called it, was meant to stir public interest in space exploration.

During the Cold War, the United States and the Soviet Union made space programs one of their top priorities. The ensuing "Space Race" drove unimaginable progress in space exploration that included human spaceflight to low-Earth orbit and the Moon and launching unmanned probes to the Moon and Mars.

Today, it seems that the next milestone in space travel will be traveling to Mars and establishing a civilization there. By making multiplanetary life a priority, humans could travel to the Red Planet, colonize it, and terraform Mars into a new home.

Before this can be done, however, scientists and engineers need to address the differences between the two planets and produce solutions that will allow people to live on Mars. While it won't be easy, humans could overcome the obstacles and adapt to life there by the end of the century.

The most seemingly impossible task that humans face in their quest for multiplanetary life is how to actually adapt to life on a planet that is so radically different than Earth. For starters, people would not be able to just walk around outside and breath fresh air. Humans can survive here where the air is made up of 78 percent nitrogen and 21 percent oxygen, whereas 95 percent of the Martian atmosphere is made up of carbon dioxide with only trace amounts of oxygen. With this composition, getting some "fresh air" would kill a person instantly. Additionally, Mars has extremely thin air, with the surface air pressure at around one percent of the sea level pressure on Earth. To walk around outside on Mars, people would need to wear pressurized, oxygenized suits.

Even with an adequate space suit, a hike across the Martian outdoors would be very different from those that people take on Earth. Due to Mars' smaller mass, the strength of gravity on the planet is only 38 percent of that felt on Earth. So, a 160 pound person on Earth would weigh around only 60 pounds on Mars.

> "If Thursday is just above freezing, then by Friday the temperature may have dropped 150 degrees."

Studies of astronauts who have completed missions of extended durations have revealed that lower gravities lead to decreased muscle mass, aerobic capacity, and bone density. Today, astronauts counteract this physiological deterioration with well-structured exercise and diet regimens, so future Mars travellers would need to be in great shape.

Another obstacle of life on another planet is the vast difference in temperatures due to the varying atmospheres and distances from the sun. Temperatures on Mars range from -153 to 20 degrees Celsius. If Thursday is just above freezing, then by Friday the temperature may have dropped 150 degrees.

Qualities taken for granted on this planet, such as the climate, air, and gravity, pose serious concerns on Mars that will need countermeasures. With all the pressurization, oxygenation, and temperature regulation, it may seem that life on Mars is more trouble than it's worth.

However, with Earth's finite resources and growing population, there may come a day when our resources run out. Humans may need another place to live with new resources to harness, and that place would likely be Mars. Being the most Earth-like alternative in the galaxy, Mars may become the second planet that humans call home.

Before anyone can adapt to life on the red rock, there first needs to be a way to get people to and from Mars. Today, spacecraft can take people to the Moon, the International Space Station, and other destinations within low-Earth orbit. However, the rockets and shuttles that will be needed to transport people to Mars are still being developed, and likely will not be available until the mid-2020s. It is currently looking like SpaceX will be the first to reach Mars, with Elon Musk announcing plans for the Big Falcon Rocket (BFR) spacecraft to make its first manned mission to Mars by 2024. BFR's reusability and ability to fly long distance will make it ideal for travelling to Mars.

These vessels are only one of the many solutions to interplanetary life that are currently being developed in anticipation of travelling to Mars. Whether or not SpaceX is the first to do it, people could terraform Mars and call the planet home in the near future, making humans an interplanetary people.

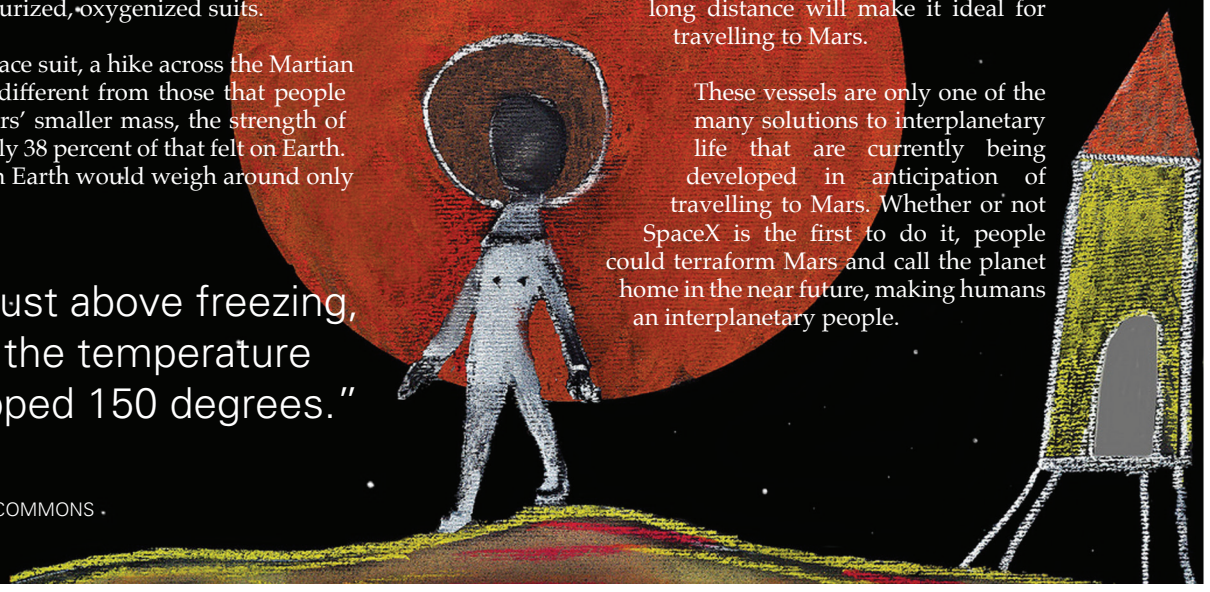


IMAGE BY GOOGLE CREATIVE COMMONS

The platypus: An evolutionary oddity

BY BINH DANG, ENVIRONMENTAL SCIENCE, 2022 DESIGN BY KAI GRAVEL-PUCILLO, ENVIRONMENTAL SCIENCE, 2021

Every species today has been pruned by the processes of evolution and natural selection to be fit for surviving in their respective habitat. Intuitively, many of their adaptations make sense—the coyote has razor sharp teeth that allow it to be a deadly hunter, the armadillo has a hard outer shell to protect itself from said predator, and the arctic fox has white fur to camouflage itself in its native environment. However, one animal has seemingly perplexed scientists for decades: the duck-billed platypus.

Looking at the platypus, none of its physical features seem unified when taken as a whole. It has the tail of a beaver, the bill of a duck, and venomous spurs in its feet. Along with all of that, it's also a mammal that lays eggs! It goes without saying that this duck-billed specimen is a wonder of the natural world. Fortunately, scientists have been interested in the platypus' history for quite some time.

The platypus is a monotreme, or a subset of mammals that lay eggs. The only other animals in this group are four species of echidna. Other groups of mammals are marsupials, such as koalas and kangaroos, and placentals, such as humans and dogs. Both of these groups of mammals give birth to live offspring, yet the platypus doesn't. This is much more similar to the reproduction pattern of a reptile—which isn't entirely wrong. A study published in Nature, led by Dr. Wesley Warren of Washington University in St. Louis, supports that comparison. In analyzing the platypus' genome, the researchers discovered that it shares genes with both mammals and reptiles. It is very likely that egg-laying was retained in the platypus when monotremes evolved from early mammals and reptiles.

> "It goes without saying that this duck-billed specimen is a wonder of the natural world."

This isn't the only trait that the platypus shares with reptiles; the venom of the platypus is very similar to that of snakes. The platypus' venom is secreted by males in higher amounts during their breeding season, which spurs the belief that it evolved to help males compete for mates. Both venoms evolved from modifications in genes that had other functions. However, these same genes evolved differently between platypus and snakes. This is a result of convergent evolution: the outcome when organisms that aren't closely related evolve to have analogous traits to adapt to similar environments or ecological niches.

The platypus' mammalian traits are its fur and its ability to lactate (despite the fact that platypus have another strange characteristic—they release milk through pores in their skin rather than teats). It was found that monotremes are an earlier branch of mammals, which is compatible with their similarities to both reptiles and mammals as well as fossil records of early monotremes showing that they existed far earlier than the other mammal groups. Collectively, this implies that lactation began at least with the monotremes (166 million years ago), if not earlier.

Platypus are more closely related to reptiles than placental mammals or marsupials, but this doesn't explain their two defining characteristics: the beaver-like tail and the duck-like bill.

The platypus tail isn't actually all that similar to a beaver's tail. Both tails aid in swimming because of their similar shapes and are likely another instance of convergent evolution; however, the beaver's tail is scaly and multifaceted. It is used for fat storage, thermoregulation of body temperature, communication with other beavers, and balancing itself when walking on land. The platypus' tail, on the other hand, is covered with coarse hairs and is used for packing down soil or remodeling a burrow.

Likewise, the bill of the platypus is only cosmetically comparable to a duck's bill. Moreover, a platypus' bill is far more intriguing than it may seem. When foraging underwater, a platypus uses its bill to sense its prey, but it does this in quite a unique way: electroreception. Its bill has small receptors that detect the electrical currents of its prey's muscle contractions, and since water is a strong conductor of electricity, a platypus can swiftly detect prey, such as shrimp, worms, and small fish. Alas, much is still unknown about the platypus' evolutionary history, so scientists still aren't certain when or how the platypus evolved a bill and electroreception. However, it has continued to serve the platypus well as a predator.

There's still a vast gap of knowledge about how the platypus came to be, but from what we know now, its peculiar physiology isn't as mysterious as it once was.

Nature (2008). DOI: 10.1038/nature06936

PHOTO BY WIKIMEDIA COMMONS

The bitter taste to rid obesity

How the signaling pathway for taste receptors influences food intake and appetite

BY CAILEY DENONCOURT, BIOENGINEERING, 2022

DESIGN BY KRISTI BUI, COMPUTER SCIENCE, 2021

Worldwide, about two billion people are considered obese or overweight, accounting for 30 percent of the world population. In the US alone, there are over 70 million individuals with diabetes and about 99 million Americans considered overweight.

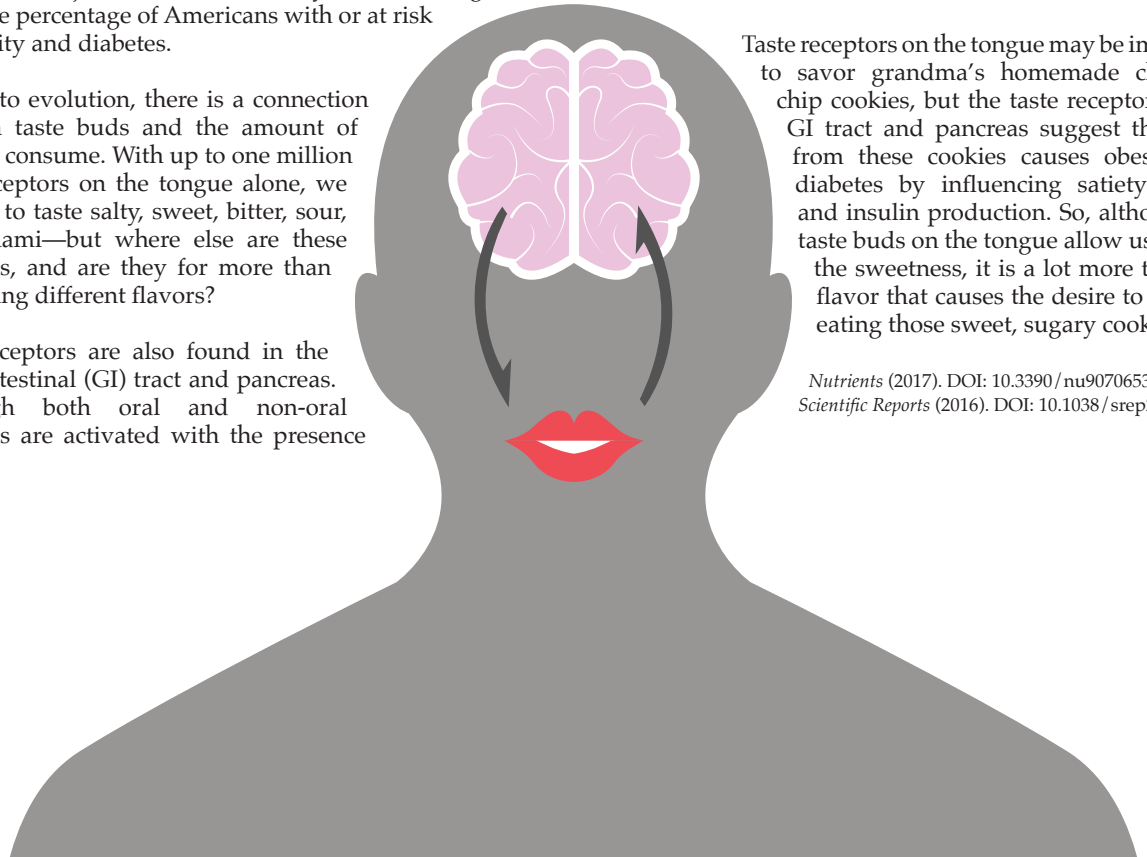
With a diet full of fast food and large portion sizes, the amount of sugar we consume greatly exceeds the necessary quota for survival. In 2016, at the Leiden Institute of Chemistry, Hans Aerts expanded on the idea that sweet taste receptor signalling plays a molecular role in the hedonic pleasure for sugar.

Through our evolutionary development, taste buds were a critical method for survival in order for our ancestors to distinguish between potentially toxic substances and nutritious ones. Sweet taste has been associated with foods high in sugars, like glucose or saccharin, that provide the necessary energy needed to survive, which in turn release a signal to increase food intake. Conversely, bitter taste has less potential to provide the energy-rich glucose molecules, thus causing a reduction in food intake. However, with the introduction of extremely sugary foods and drinks—like candy and soda—into the human diet, there is an unhealthy increase in the amount of glucose in our bodies. This increase in accessibility and amount of sugar in our diet initiates the feedback loop for more sugar, additionally escalated through the large portion sizes. As a result, Americans in particular have fallen subject to this evolutionary trait, resulting in a large percentage of Americans with or at risk for obesity and diabetes.

Thanks to evolution, there is a connection between taste buds and the amount of food we consume. With up to one million taste receptors on the tongue alone, we are able to taste salty, sweet, bitter, sour, and umami—but where else are these receptors, and are they for more than just tasting different flavors?

Taste receptors are also found in the gastrointestinal (GI) tract and pancreas. Although both oral and non-oral receptors are activated with the presence of various tastants, the chemical molecules that stimulate sense of taste, the receptors serve different roles in their message to the brain. Oral taste buds allow us to taste the difference between a sweet fudge sundae and a bitter chocolate bar. However, the receptors in the GI tract monitor the nutrients taken in by the body during digestion and communicate to the hypothalamus and brainstem, areas of the brain particularly known for their control of metabolic regulation, thus impacting food intake and appetite. This was demonstrated in 2007 by researchers at the Mount Sinai School of Medicine where the activation of the sweet taste receptors in the small intestine led to the release of hormones, like GLP-1, that stimulated the release of insulin and satiety signals.

However, any disruption to this signalling pathway between the sweet taste receptor and the nervous system is thought to contribute to the development of type II diabetes and obesity. When observing individuals with type II diabetes, researchers have seen a decrease in the sensitivity of sweet taste receptors, which results in increased consumption. Conversely, the bitter taste receptors in the GI tract are known to release a hormone, ghrelin, which causes a short period of increased appetite. But, as shown in mice, the short appetite was followed by a prolonged decrease in food intake. This same relationship is found within humans, thus opening the possibility to help treat obesity with a 'bitter-taste' pill that would cause a long-term feeling of satiety and decrease their overall food intake.



Taste receptors on the tongue may be important to savor grandma's homemade chocolate chip cookies, but the taste receptors in the GI tract and pancreas suggest the sugar from these cookies causes obesity and diabetes by influencing satiety feeling and insulin production. So, although the taste buds on the tongue allow us to taste the sweetness, it is a lot more than just flavor that causes the desire to keep on eating those sweet, sugary cookies.

Nutrients (2017). DOI: 10.3390/nu9070653
Scientific Reports (2016). DOI: 10.1038/srep29094

PHYSICISTS COLLIDE OVER FUTURE OF COLLISIONS

BY JAMESON O'REILLY, PHYSICS & MATH, 2019

DESIGN BY KYLA VIGDOR, DESIGN, 2021

The Large Hadron Collider (LHC), a particle accelerator in the form of a 27-kilometer ring of superconducting magnets, is the largest and most complex machine in the world. Prior to and during its construction, many particle physicists predicted that it could be used to discover the origin of dark matter, extra dimensions, evidence of supersymmetry, and more. Only one of the big expectations was fulfilled: the discovery of the Higgs boson in 2012.

Finding the Higgs was a major achievement, as it completed the Standard Model of particle physics, and in January, CERN, the European laboratory that runs the LHC, proposed a sequel: the 100-kilometer Future Circular Collider (FCC). Proponents of the plan have used many of the same taglines as the original LHC proposers did, but the perceived failure of the LHC to provide these results is now being held against them. In a recent *New York Times* op-ed, Dr. Sabine Hossenfelder, a theoretical physicist who used to work on particle physics theory, argues that we should not build a new collider when we have no particular reason to believe that it will provide new discoveries.

> "[The experiments] teach us something fundamentally new in spite of, and often because of, the failure to satisfy particular predictions."

Hossenfelder, currently a Research Fellow at the Frankfurt Institute for Advanced Studies, contends that the particle physics community has no particular reason to expect anything new at the higher energies that the FCC would probe. Theorists have proposed hundreds of possibilities for physics beyond the Standard Model but few convincing arguments for which theories are more likely. Thus, according to Hossenfelder, this theorizing is "little more than guesswork." While it was possible that the LHC could have answered many fundamental questions, there was no strong reason to expect anything besides the Higgs boson, and the FCC does not even have that.

The argument is essentially a practical one, as Hossenfelder suggests that we focus on diverting the billions of dollars that would go into building the FCC to many medium-sized projects. Her examples include things like astrophysical particle searches and experimental studies of the interface between gravity and quantum mechanics. However, many scientists, including Professors Chanda Prescod-Weinstein and Tim Tait, particle physicists at the University of New Hampshire and the University of California, Irvine, respectively, have pointed out that science is not meant to be a constant string of discoveries.

As Prescod-Weinstein and Tait write in *Slate*, science is an effort to more fully understand our universe, and null results like those from the LHC are an important part of that. The experiments run at the LHC provide access to energy scales that humans have never been able to explore previously. They teach us something fundamentally new in spite of, and often because of, the failure to satisfy particular predictions. For example, if the LHC had not found the Higgs boson, it would have been disappointing, and some may have called it a failure, but physicists would have had to rethink many of the ways that we understand the universe.

Professor Scott Aaronson, a quantum computing theorist at the University of Texas at Austin, makes a similar point on his popular blog, *Shtetl-Optimized,* and draws an analogy to his own field. Even if building a quantum computer is impossible, learning this fact by trying to build one will force us to rethink quantum mechanics, currently our most well-accepted physical theory. Regarding the proposal to fund many smaller projects rather than one massive FCC, Aaronson also points out that raising the energy of a collider allows hundreds of theories to be tested at once, rather than just one or two.

He also brings up the story of the Superconducting Supercollider (SCSC). The SCSC was a proposed particle accelerator that began construction in Texas but was cancelled in 1993 due to budget concerns. It would have surpassed even the current energy of the LHC, but many physicists from other subfields of physics complained that too much money that could be supporting their research was instead going into construction of the SCSC. Unfortunately, even after the SCSC project was terminated, the money that would have been spent on it never made its way to other researchers.

If the FCC is never built, there is no guarantee that other projects will be funded in its absence. If it is, there is no guarantee that it will make any significant discoveries, but this would be interesting and informative in its own right. However the money is spent, there is no way to guarantee a maximum number of discoveries per dollar. Rather, particle physicists and scientists more broadly advocate for exploration for its own sake when they make such ambitious proposals.

TO ALL THE PODCASTS I'VE LOVED BEFORE

A review of current science podcasts

BY CICELY KREBILL, BIOLOGY, 2019

DESIGN BY LILLIE HOFFART, ENVIRONMENTAL SCIENCE, 2022

With their ability to bring a story to life through the sounds and recordings of interviews and the effortless way in which they drown out a long commute, podcasts have always been my favorite form of storytelling. As a frequent source of inspiration for my articles in the past, it felt only fitting to review some of my favorite science podcasts.

MY FIRST LOVE

Radiolab: The Argentine Invasion

Radiolab is that podcast that will always hold a special place in my heart. It was my first introduction to science communication and showed me that you could bring about a hilarious story that is wholeheartedly rooted in science. With its kicky music and sound effects, this podcast breathes life into any research it presents.

The first episode that I ever listened to was about something as simple as ants, and yet, I couldn't turn it off. Because of that, it's the one I love the most. In *The Argentine Invasion*, the hosts, Jad Abumrad and Robert Krulwich, follow a multitude of ecologists, evolutionary biologists, and entomologists as they study Argentine ants: an unusually aggressive type of ants that kill ants from other colonies. Their atypical aggression allows them to stay so genetically pure that they recognize each other, regardless of what continent they come from, as the part of the same super-colony.

Listen to these hosts react to how a group of ants fought their way from a breeding ground in Argentina to the sidewalks of California in a comically human way and you'll barely notice as the 20 minutes of your day fly by.

THE PROFESSIONAL

Nature Podcast: Gravity's Big G and the Evolution of Babies

Nature Podcasts feel like your significant other coming home from work and telling you everything about what's going on in their field. Some of it's interesting and exciting and some of it is, to be frank, a little boring. They're the episodes you aren't immediately hooked by, but the ones you know you are better for after listening to. Weekly episodes review updates in science, hosted by Shamani Bundell and Adam Levy, quickly informing you about the goings on in the realm of science. With a wide variety of topic coverage, I feel constantly pulled out of my bubble, immersed in all types of research, including chemistry and physics. In this episode, the hosts introduce the struggle for researchers to measure the exact value of the gravitational constant as well as the evolution of the mammalian baby. Though vastly different topics, experts in the field are interviewed in both cases, and the hosts present a no-nonsense statement of facts as to why this information is pertinent and how it compares to what we've previously known.

These episodes allow you to keep up to date in all things science and are a gateway to sounding impressive at your next dinner party.

THE NARCISSIST

Two Scientists Walk into a Bar: Ouch! Our Bodies Our Pain

Two Scientists Walk into a Bar is unique in the realm of science podcasts in that it only really ever focuses on itself. Hosted by Jane Grogan, a principal scientist of cancer immunology at Genentech, this platform is used to present on research currently going on in the company. Though focusing solely on Genentech's work, the podcast does not lose its listener's interest. In one of my favorite episodes *Ouch! Our Bodies Our Pain*, Jane Grogan hosts Morgan Sheng, the Vice President of Neuroscience Biology at Genentech to discuss the evolution of pain and its importance for our survival. They discuss Genentech's current research attempts to manage chronic pain without impacting our critical ability to sense acute pain.

Although Sheng and Grogan's discussion focuses largely on research, they do so with a great bit of entertainment. Give it a listen if you want to hear about how a family of street performers in Pakistan helped spark the current research into painkillers.

As with anyone that likes to share a lot about themselves, this podcast is the opportunity to almost get inside the mind of a company, to learn about the way they make their decisions in research. To me, that's absolutely fascinating.

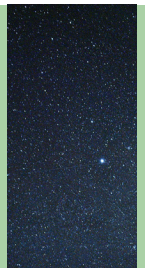
4 FREE APPS TO HELP YOU EXPLORE THE WONDERS OF OUR WORLD

BY ERICA YEE,
INFORMATION SCIENCE & JOURNALISM, 2020

That device you have in your pocket is great at helping you stay connected with friends and navigate around the city. Our smartphones can also be incredible tools to explore different layers of the world around us. As digital technology keeps improving, it's easier than ever to use sensors and virtual reality to create more educational and fun experiences. Here are a few of the many apps that enable you to see the world just a bit differently.

Scan the QR codes using your phone camera to go to either the Google Play Store or Apple App Store.

STARGAZING



Astronomy apps bring the wonder of stargazing down to earth, accessible to anyone curious enough to point a phone at the sky. Use these augmented reality apps to spot and identify constellations, planets, satellites, and more.

iOS:
Night Sky

Android:
SkyView Free

OBSERVATIONS FOR NASA

You can also turn your phone into a portable laboratory to contribute to official scientific research using the NASA Globe Observer app. Take pictures and record conditions about cloud cover, land cover, or mosquito habitats, then submit the collected data to NASA. These observations are used by NASA scientists to validate, interpret, and understand satellite data from space.

iOS:
GLOBE Observer

Android:
GLOBE Observer

ART AND HISTORY

If you want to take a break from the present-day world and dive into history, check out the BBC's Civilisations AR app. This app provides you with a virtual collection of dozens of to-scale historic artifacts. You can place an ancient Egyptian mummy in your living room and then walk around it, zooming in for closer study.

iOS:
Civilisations AR

Android:
Civilisations AR

BLINDNESS

For an altogether different experience in a world without sight, you can download Notes on Blindness: Into Darkness. Released as both a feature film at Sundance 2016 and an immersive virtual reality project, the interactive true story recreates what it was like for author John Hull to slowly became totally blind. You can explore both the sensory and psychological effects of blindness through Hull's actual audio diary. The virtual reality experience is viewable on a smartphone with or without a headset.

iOS:
Notes on Blindness VR

Android:
Notes on Blindness VR

DESIGN BY KATIE GREEN, BIOENGINEERING, 2021
PHOTOS BY WIKIMEDIA, PXHERE, AND PUBLICDOMAINPICTURES

Do college students really receive jury duty more often than others?

BY HANNAH BERNSTEIN, JOURNALISM & ENVIRONMENTAL SCIENCE, 2021

When looking in any dorm building mail room, it's hard not to notice what seems like a million jury duty summons postcards in everyone's boxes. Living in Boston with the highest colleges per capita in the United States, it makes sense that there's just more college students on the list. But do college students really receive jury duty more often, and why?

"[A jury office's] ultimate goal should be that whoever's on trial has a jury of their peers, that everybody has an equal chance to face jurors that look like the population," said Robert Boatright, a professor at Clark University who has done previous research on jury selection and enforcement.

But he says it's unlikely more college students are actually getting jury duty.

"It seems to me like I get summonses more frequently here in Massachusetts than I did when I lived in other places," he said. "On the other hand, the thing to consider is that Massachusetts is extremely generous about letting you defer your jury service … so that's an effort to try to address the needs of college students or people whose jobs won't allow them to take off that particular day."

Beyond the anecdotal evidence, let's take a look at the individual chances of serving on a jury using data from a FiveThirtyEight study in 2015. In a given year, according to an estimate by the National Center for State Courts, 32 million people are summoned and eight million of those actually report. The 24 million difference is a result of undeliverable postcards, failures to appear, and more. There isn't more recent data, so there's not even a good way to estimate a normal eligible person's chances of serving, let alone college students.

There's also another perspective on this. Most jury selection systems use a basic list randomizer to select who gets summoned and when. Actual randomizers aren't really what humans perceive as random—for example, Spotify playlists use an algorithm, rather than a randomizer, so the same song or artist doesn't come up twice in a row. A simpler example comes from basic chance theory: Each time a coin is flipped, there is the exact same chance it will be heads or tails, each time. Each flip doesn't impact the previous flip, so it's entirely possible to get the same result twice (or more) in a row. Obviously, juror lists are a lot longer, but the same basic idea applies.

In July 2018, The Curiosity Desk at WGBH looked into a similar question: How does Massachusetts decide who gets summoned for jury duty? They interviewed the state's jury commissioner, Pamela J. Wood. Here's what she said about their algorithm: "It is done randomly by computer. We're not over here drawing names out of a hat."

Wood said the office uses software called Jury+ which uses a "master juror list" to randomly select names. That list is developed from a mandatory municipal census, which Massachusetts requires cities and towns to submit. Because it's a town census and not a driver's license list, for example, college students with local dorm addresses get pulled in as well. That's also unusual because many states don't allow out-of-state college students to serve.

Wood referenced the same coin example: "If you flipped a coin three or four times in a row and got heads every time, you might think it's unusual, but you'd understand it was random and it wasn't worth calling the Guinness Book of World Records."

She cited a 10 percent chance of receiving a summons each year, no matter when you last received one. If you serve on a jury, you're exempt for three years before your name goes back in the hat.

So, do college students receive jury duty more often in Boston? Right now, it seems like the answer is no. Instead, because Massachusetts is ahead of other states in many ways when it comes to jury duty summonses, college students make it on the list here when they might not have in other states.

But, Boatright had one last thing for college students facing a jury summons to consider:

"It's a good thing to do jury duty," he said. "It's annoying to get summonses, but people generally report that it was a worthwhile experience. If you were on trial, you wouldn't want to show up and have a room full of retired people sitting and judging. You'd want the jury to look like the population."

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DESIGN BY LILLIE HOFFART, ENVIRONMENTAL SCIENCE, 2022

A fond farewell

A tribute to the NU Sci seniors

PHOTOS BY GUS MUELLER
DESIGN BY LILLIE HOFFART, ENVIRONMENTAL SCIENCE, 2022

As we enter our 10th year of publication, we must sadly say goodbye to some of our wonderful members. Meet NU Sci's class of 2019—composed of high achievers, motivators, and go-getters alike. These writers, editors, marketers, and webmasters have played a huge part in making our magazine what it is today. Join us in congratulating them on their successes and wishing them luck in their future endeavors.

1 Amanda Bretti

Amanda has been a member of the web team and a writer for NU Sci for the past three years. Her most recent article,"A Step Toward the Future," is about the design of musculoskeletal robots. After graduation, Amanda will be staying near Boston and working in the biotech/pharma industry.

2 Adrianna Graziano

Adrianna has truly enjoyed the last few years as a staff writer, editor, and outreach ambassador for NU Sci. A Biology major and Women's, Gender, and Sexuality Studies minor, her favorite articles integrate science, identity, and outreach education. Specifically, these include "Coloring in the Blanks" (Issue 34: Color) and "Shedding Light on Invisible Disabilities" (Issue 37: Interaction). She wants to thank everyone she has met in NU Sci for the memories, laughter, and lessons. Moving forward, she'll be taking what she has learned to make impactful change within the scientific community in addition to communicating knowledge across audiences in an accessible manner.

3 Jackson Griffiths

Cell and Molecular Biology major Jackson has worked as a marketer, head of marketing, co-head of outreach, and president throughout his time with NU Sci. He has loved doing research and writing facts for our social media pages, planning events, and helping put together each amazing issue. Jackson will be taking one to two years off to do research in the Animal Regeneration Research Lab at Northeastern University before he starts working towards his PhD.

4 Cicely Krebill

Biology major Cicely has been a writer, editor, and senior editor at NU Sci during her five years at Northeastern. Out of all of her experiences at NU Sci, she will most miss the chaos and hilarity of article assignment meetings. After graduation, she will take some time to soak in one last Boston summer, and then will head to medical school in the fall.

5 Gauri Narayan

Over the last five years, Biology major Gauri has written for NU Sci several times and has recently joined the Marketing Team, helping to manage the Instagram page. She has loved having an outlet to combine her interests in writing and science, and she hopes to carry the skills she has developed here into her future career. After graduation, Gauri will be looking for work in the Boston area, hoping to land a marketing or communications position in the biotechnology/pharmaceutical industry.

6 Heather Offermann

Heather is Behavioral Neuroscience major who has been a writer, editor, and head of communications during her four years in NU Sci. Some of her favorite articles she has written are "A Color's Worth a Thousand Words" (Issue 34: Color) , "The Beautiful Brain: An MIT Museum Showcase" (Summer 2018), and "What's His Face? Painting Faces with AI" (Issue 38: People). Her involvement with NU Sci has allowed her to find a community that shares the interdisciplinary love for science and humanities. After graduation, Heather plans on staying in Boston to work on applied contemplative neuroscience in clinical settings.

7 Jameson O'Reilly

Physics and Math major Jameson has been a writer and editor for NU Sci for almost five years and this year was a Senior Editor and Staff Writer. His favorite articles include one about snails for Issue 34 and quantum mechanics in Issues 33, 36, and 37. After graduation, he will try to build quantum computers while pursuing a PhD in Physics.

8 Rafi Razzaque

An Environmental Science major who found his feet at the cornerstone of environment and engineering, Rafi is sad to conclude his time with NU Sci. Having been a writer, editor and treasurer over the past four years, he hopes this won't be the end of his involvement in scientific writing. In particular, his articles on American water infrastructure, engineering a two-hour marathon, and hypothesizing on the alarming possibility of the earth ceasing to spin rank among his favorites. A Boston native, Rafi hopes to stick around after graduation. Catch him training to run a marathon of his own, someday!

9 Brynn Vessey

Behavioral Neuroscience major Brynn has been a writer and editor for NU Sci during her time at Northeastern. Her favorite articles to write were "The Ocean Needs You, Not Your Trash," and "Don't Mind the Brain: A Conversation with Professor Satpute." Brynn will stick around Boston to work in the Psychiatry Neuroimaging Lab at Brigham and Women's Hospital before obtaining her PhD in Neuroscience. She hopes to integrate science and society in a manner worth writing about one day.

10 Sage Wesenberg

Sage, a Biology major with Journalism and Ethics minors, has been writing for NU Sci since her freshman year. Since then, she's been an editor, head of communications, and editor-in-chief. One of Sage's favorite articles to write was "Senses to the Rescue" from Issue 25: Strategy. As an aspiring science writer, NU Sci has been an incredibly impactful part of her career at Northeastern as it allowed her to gain experience, new perspectives, and connections into the world of science journalism. Sage will take these experiences with her as she pursues the science communication field after graduation.

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