Columbia Science Review

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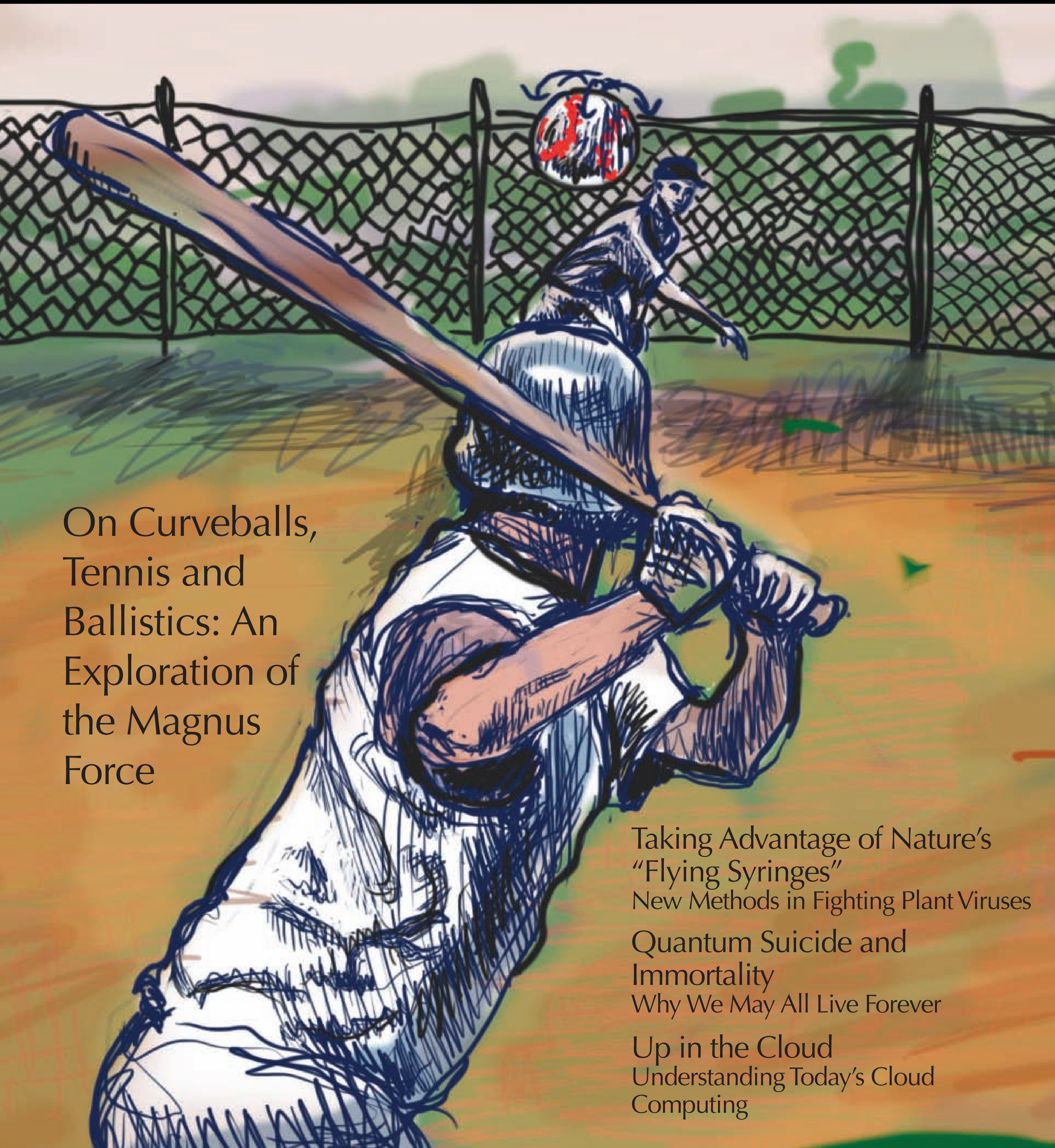

On Curveballs, Tennis and Ballistics: An Exploration of the Magnus Force

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The Columbia Science Review strives to increase knowledge and awareness of science and technology within the Columbia community by presenting engaging and informative articles, in forms such as:

- Reviews of contemporary issues in science
- Faculty profiles and interviews
- Editorials and opinion pieces

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Columbia Science Review

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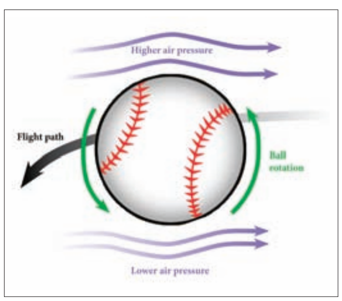

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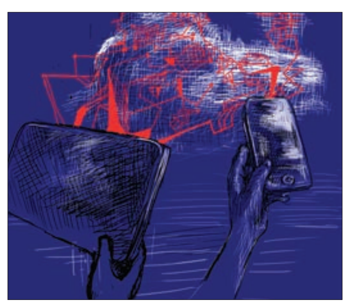

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Up in the Cloud

Peixuan Guo
Emma Meyers
Ari Schuman
Sauleha Kamal

Cocktail Science

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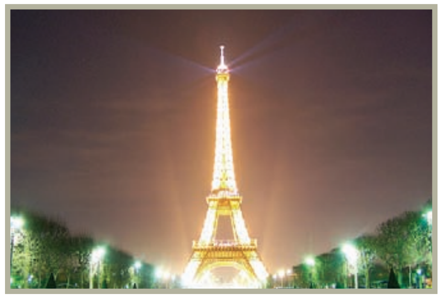
Digital transmission of information is never perfect. Due to noise, errors are often created in the process. Researchers at MIT recently invented a new error-correcting scheme that is mathematically proven to produce the fastest data transmission rate possible. In the new scheme created by Gregory Wornell (MIT), Uri Erez (Tel Aviv University), and Mitchell Trott (Google), one long error-correcting codeword is created. However, this codeword is not transmitted as a whole, but as successive pieces. Each individual piece and combinations of pieces also act as error-correcting codewords in themselves. For example, a codeword may be 40,000 symbols, but broken up in pieces of 2,500 symbols. The first 2,500 symbols may be designed to decode messages at low noise levels. If the noise level is too high, the receiver will need the next 2,500 symbols to produce a functioning codeword. This process continues until the receiver receives just enough symbols to correct all the errors, at which point the receiver signals to the transmitter to stop. The researchers proved mathematically that this method produces the fastest data transmission rate possible. In an age where much of our information is transmitted digitally, this discovery will help make our communication networks more efficient.

Stressed? You're not alone—which is why millions of Americans turn to the practice of yoga for relaxation. But they may be getting more than just mental health benefits from the de-stressing exercise: recent studies are reporting a slew of possible physical gains from the practice as well. Dozens of small studies suggest that yoga may help people with heart disease lower cardiovascular risk factors like cholesterol, blood sugar, and stress hormone levels, as well as ease palpitations and sooth the symptoms of heart failure. These preliminary studies are small, but have established a strong jumping off point for current randomized and controlled trials to fully assess the benefits of yoga in cardiovascular disease. Doctors are already endorsing yoga for heart health in their practices; the department of cardiothoracic surgery at New York Presbyterian Hospital even offers its patients guided sessions in order to maximize heart disease prevention. So, next time you're feeling under pressure, take some time out and hit the mat. Your heart will thank you.



Paris can be stunning—literally. For an unknown reason, tourists from Japan who visit the city are having psychiatric attacks on arrival (or, in some cases, many months afterwards). Called "Paris Syndrome", the disease's onset seems to be caused by a break between the fantasy of Paris and the reality of a city. The theory behind it is odd: scientists believe that the tourists are essentially experiencing severe culture shock, and that the particular politeness of Japanese society juxtaposed against experiences with rude or unhelpful people in Paris causes the breakdowns. About a dozen tourists experience these breaks each year, but many have had previous psychological problems. Interestingly, similar syndromes occur in other cities. In Florence, tourists experience Stendahl Syndrome, which occurs due to an overwhelming aesthetic experience and causes similar anxiety issues. Jerusalem Syndrome is very similar to Paris Syndrome, but can occur in religious people or in people with no history of mental illness. In this latter case, the patients follow a very specific course: they become anxious, separate themselves from the group, groom themselves, put on a toga, and chant verses from the Bible until they reach a holy site.

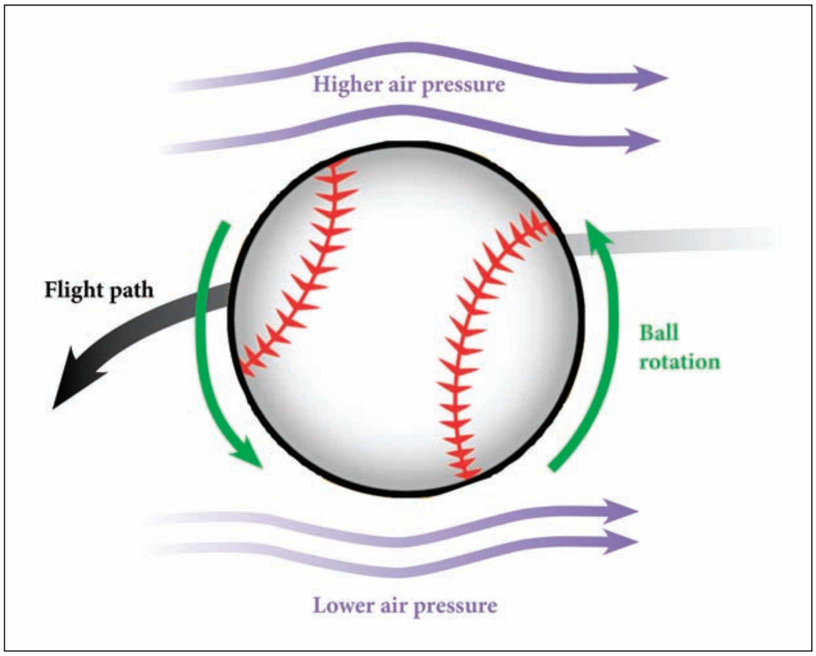
Singing birds have always been romantic, representing peace and happiness in everything from Wordsworth's poetry to Disney's Snow White and the Seven Dwarfs, but what do we make of singing mice? According to a team of researchers at the University of Veterinary Medicine in Vienna, male house mice serenade the females in hopes of winning their affections. Recordings from wild house mice show that they emit ultrasonic vocalizations (USVs) during courtship. The USVs are surprisingly complex; they have varying frequencies and even resemble birdsongs. Female mice have shown attraction to playbacks of these recordings, especially to recordings of unfamiliar mice as opposed to those of siblings. The scientists used urine from female mice as cues to indicate the presence of potential mates. They found that wild mice are more prone to producing sounds of higher frequency than laboratory mice indicating that environment affects the song. However, 20% of the mice did not produce the sounds and it remains unclear whether they're just not romantic enough or simply stressed. Still, one thing is clear: Jerry singing opera music on Tom and Jerry wasn't as far off from reality as it seemed at the time.

On Curveballs, Tennis, and Ballistics: An Exploration of the Magnus Force

Peixuan Guo
Illustrations by Allison Cohen and Laura Ye

It's the bottom of the ninth inning with one out. The tying run is on second base. *I just need to get a hit*, thinks the batter as he waits for the next pitch. Here it comes. The ball flies out of the pitcher's hand. *It's high, at least a foot above the strike zone*, thinks the batter. The batter relaxes his grip on the bat. He's not going to swing. But then something strange happens. As the ball gets close to the plate, it suddenly begins to drop. *Probably still too high*, thinks the batter. But to his surprise, the ball drops even faster. It might even reach the strike zone at this rate! The batter tries to adjust, but he cannot re-grip the bat in time. The pitch crosses the plate and manages to scrape the top of the strike zone. What happened?

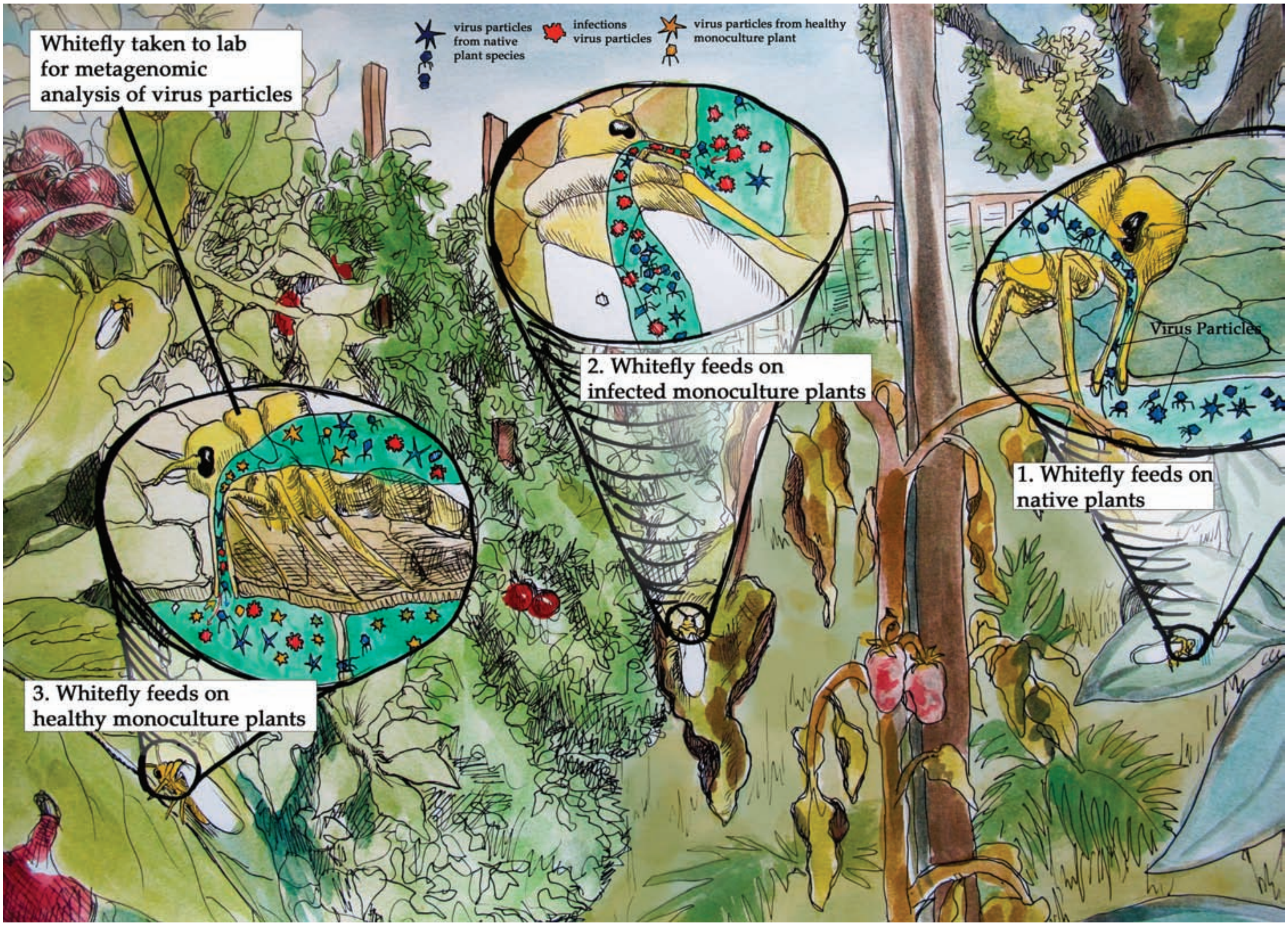
The Magnus force happened. Also called the Magnus effect, this phenomenon in fluid dynamics is responsible for the sinking motion of a curveball. Isaac Newton first documented this concept in 1672 after observing its effects during a game of tennis. Although first described by Newton, the force itself is named after German physicist Heinrich Gustav Magnus, who wrote papers on it in 1852 after researching trajectories of rotating artillery shells for the Prussian Artillery Commission.



In general, the Magnus force acts on all spinning objects moving in a fluid, which is any other substance that does not have a fixed shape. As the object travels, the fluid pushes back on the object in the opposite direction of where the object is traveling, creating a drag force backwards. The object's spin causes one side of the object to move in the same direction as the object's overall motion. Let us call this side the "forward-moving" side. Meanwhile, the other side is traveling in the opposite direction of the object's overall motion. Let us call this side the "backward-moving" side. The velocity generated from the spin is added to the overall velocity on the forward-moving side and subtracted from the backward-moving side. As a result, the drag is greater on the forward-moving side than the backward-moving side, creating higher pressure at the forward-moving side. The pressure difference creates a force perpendicular to the line of motion towards the backward-moving side.

The Magnus force appears frequently in ball sports. The curveball mentioned earlier is made from the Magnus force through two key ingredients: the vigorous top-spin a pitcher employs and the air (a fluid) that the ball travels through. The top-spin causes the top of the ball to move faster, resulting in greater drag at the bottom. The higher pressure at the top creates a Magnus force that pushes the ball down. Golfers, on the other hand, put heavy back-spin on the golf ball. This back-spin creates a Magnus force that pushes the golf ball up. As a result, a golf ball with backspin stays in the air longer and travels a farther distance. In table tennis, high level players are able to create all kinds of weird motion in different directions by manipulating the spin on the ball, making it harder for the opponent to volley. This is true in tennis as well, where top players utilize spin in order to create deceptive motion in the ball. For example, Rafael Nadal uses a forehand with very heavy top-spin. This top-spin creates a Magnus force that pushes the ball down. As a result, the ball hits the ground much faster at a lower angle, which gives the opponent less time to react to a sharper bounce.

The Magnus force has many applications outside of sports as well. Henrich Magnus' original research was on ballistics. When fired, a bullet spins and must pass through air. Thus, the Magnus force will affect the bullet. However, because of the bullet's high velocity and other more powerful forces, such as wind and aerodynamic drag, the Magnus force will have little effect on the overall flight path of the bullet. Instead, the Magnus force may change the yaw angle of the bullet, i.e. the angle of the bullet's head with respect to its flight path. This either stabilizes the bullet (if the Magnus force decreases the yaw angle so that the bullet's head is in line with the bullet's flight path), or destabilizes the bullet (if the Magnus force increases the yaw angle so that the bullet head points outwardly from the bullet's flight path). A more stable bullet faces less drag and pierces the target more cleanly upon impact. On a much larger scale, there is even speculation that the Magnus effect affects galaxies. Indeed, the asymmetries in disk galaxies may be due to the Magnus effect acting on the outer edges of the gas disk. This is still an area of ongoing research and no definite conclusion has been reached. Regardless, it is clear that the Magnus force should never be overlooked.



Taking Advantage of Nature's "Flying Syringes"

Article and Illustration by Allison Cohen

Plant virus infections continue to threaten crop yields throughout the world. However, newly emerging viruses, such as geminiviruses, have only recently become a mult-million dollar threat to the monoculture crops we rely on to feed the world's growing population. According to Anne Simon Moffat, writing for Science, geminivirus infections alone caused $140 million in damage to the tomato crop during Florida's 1991 and 1992 growing season. In many developing countries, crop loss due to plant viruses can wipe out the livelihood of indigenous peoples, leading to poverty and famine. A virus's ability to take over host cellular machinery in order to replicate and infect other organisms makes it difficult to target infected cells without damaging healthy cells. Currently, the only real defense against plant viruses is prevention. Luckily, since plants do not move, it is unlikely for plant viruses to spread as quickly as animal viruses do through direct contact between infected and uninfected individuals. Only plants that happen to grow close enough together to touch can transfer viruses this way, and only if the plants have wounds that allow the virus infection to penetrate the plant's tissue in the first place.

The two main mechanisms by which plant viruses spread are through the decomposition of dead infected plants into soil and, more commonly, through the tissues of insects that feed on infected plants: the virus's insect vectors. These dispersion methods are the targets of widely used preventive measures against plant virus endemics. Specifically, agronomists, individuals responsible for implementing agricultural practices, use virus-free planting material and employ pesticides to kill the problematic insect vectors.

Recent investigations have led to the development of treatments that mimic the use of vaccines in humans. Genes that encode functional or partially functional virus coat proteins can be inserted into plant chromosomal DNA. Once the plant produces these viral proteins, real viruses are unable to replicate themselves during an infection due to complex defense mechanisms employed by the plant. Other treatments combine the insertion of viral genes with the activation of ribonucleic acid (RNA) silencing mechanisms to "turn off" the expression of virus genes. Although potentially more effective and environmentally friendly than traditional antiviral methods, genetically engineered resistance methods are still not fully developed. The technology requires prior knowledge of problematic plant viruses, many of which constantly swap genetic material and evolve. Also, novel plant viruses that are not yet economically problematic can evolve traits that enable them to cause even more damage.

To determine which viruses to target for genetic engineering, one could look back at a history of infections in the plant of interest and choose viruses that have caused major problems in the past. This approach does not take into account newly emerging pathogens. As DNA sequencing has become easier and cheaper over the past few years, researchers have created new methods of identifying pathogenic viruses. These involve purifying virus particles from a sample, extracting the viral DNA, and using various molecular methods that amplify and cleave DNA (PCR, restriction enzyme digestion) to obtain either a fragment of DNA or the whole genome for sequencing and identification. Such methods allow researchers to make more accurate diagnoses, allowing them to better engineer resistant plant strains. However, sampling diseased plants solely for pathogenic viruses limits investigators to detecting only very infectious and problematic viruses. Also, these disease-causing viruses targeted in these investigations exist in plant tissues in such low numbers that they are difficult to detect. Once again, the screening method most likely fails to pick up emerging or milder viruses or even pathogenic viruses that exist in the tissue in low concentrations.

Researchers at the University of South Florida are developing a new method of sampling virus diversity that takes advantage of an insect vector's ability to accumulate viruses from a variety of plant types across time and space. Many plant viruses have evolved complex mechanisms allowing them to remain in the insect vector long enough to be released into a new plant host during subsequent feedings. Virus families typically vary in the extent to which they inhabit the insect vector. Some merely remain in the insect's digestive tract for a short time. Others leave the gut and enter into the insect's hemolymph, or circulatory fluid, where they can be retained for long periods of time before being transported to the insect's salivary gland for release. Some can even replicate inside the insect. To accomplish this, viruses have developed certain molecular mechanisms that only work within a specific insect, as each virus within a genus can only be spread by insect vectors of one genus. For example, viruses of the genus Begomovirus are transmitted solely by whiteflies of the genus Aleyrodidae while Potyviruses are transmitted solely by aphids of the genus Aphididae. These vectors, especially the highly mobile ones like whiteflies, can accumulate viruses from the many plants they feed on, making the insects both harmful agents for virus spread and useful tools for novel virus discovery as well as the monitoring of known viruses. Whiteflies, for example, will feed on crops with disease-causing infections, crops with benign infections, and weeds infected by viruses that often contain new genetic material that allow benign viruses to become pathogenic. Therefore, whiteflies can effectively sample viruses in circulation within a community of plants.

A team of researchers led by Terri Ng and Mya Breitbart of the University of South Florida has proposed using the sequencing of small fragments of all of the DNA in an environmental sample on insect vectors to evaluate the kinds of viruses they contain. Such a combination is called vector enabled metagenomics (VEM). Using this technique, a researcher can obtain sequence and identification data as well as prevalence data for viruses without prior knowledge of what to look for. VEM is especially useful for discovering novel viruses transmitted by vectors. Although not all viruses detected are necessarily disease causing or emerging pathogens, many of the detected viruses could become problematic in the future. Once perfected, VEM could be used to monitor the spread of viruses to stay one step ahead of infections. In case a virus does become a problem, researchers would then have its entire genome available, allowing for more effective detection and prevention. As the world's population continues to grow rapidly, we need to take better, more proactive steps to keep plant viruses from wiping out our food supply. Insect vectors may prove an unlikely ally in the battle against plant viruses.

Why We May All Live Forever: Quantum Suicide and Immortality

PALMER GREENE
ILLUSTRATION BY EVELYN WARNER

What would it be like to live forever? According to one interpretation of quantum mechanics, we may all find out.

Most people have heard of Schrödinger's Cat. A cat is locked inside a box with a vial of poison, a Geiger counter, and a small amount of radioactive material. There is a 50 percent chance that one atom of the material will decay over the course of an hour, which will cause the Geiger counter to activate a hammer and smash the vial of poison, killing the cat. Alternatively, there is an equal chance that nothing happens at all and the cat survives. The hitch of the experiment is that, until the box is opened and the cat is observed, the cat exists in two states at once: it is simultaneously alive and dead. This illustrates the principle of quantum uncertainty. The cat's fate is only determined when somebody opens the box.

All is well and good for the person opening the box, but what about the cat? Does it experience being both alive and dead at the same time? To answer these questions, cosmologist Max Tegmark of MIT posed a thought experiment called quantum suicide, in which a scientist operates a machine connected to a gun pointed at his own head. Every time the scientist presses a button, the machine measures the spin of a quark, the tiny elementary particle that makes up almost all of the matter in the universe. Quark spin has an equal probability of being either up or down every time it is measured. If it is down, the gun fires and the scientist is killed instantly. If it is up, the gun does not fire and the scientist lives. With this in mind, the scientist-who is clearly brilliant-presses the button:

Click.

Nothing happens. The scientist presses the button again, and the quark is measured once more:

Click.

Somehow the scientist is still alive. One might think that this is purely a product of chance. He has a 50% chance of surviving one push of the button, 25% chance of surviving two pushes, and so on, with each push cutting his chance of survival in half. However, the scientist hits the button again and again, one hundred times, a thousand times, pushing the button until he gets hungry and walks away. There is nothing wrong with the machine; the scientist has simply beaten the odds. What could explain the scientist's impossible luck?

To understand what is happening, one must be familiar with a decades-old debate among physicists over the real-world interpretation of the Uncertainty Principle. First described by Werner Heisenberg in 1927, this central doctrine of quantum physics states that a particle's position and momentum cannot be known simultaneously to an arbitrary degree of accuracy. In other words, the more precisely we know a particle's momentum, the less precisely we can know of its position, and vice versa, because it is impossible for a scientist to observe a particle's position without disturbing its momentum. The momentum then has a range of possible values, and is not fixed until the particle is measured again in a different observation.

The idea that a particle can exist in an indeterminate range of possible states at the same time was a major point of contention during the early years of quantum physics. Albert Einstein refused to accept that quantum events occur according to probability distributions and not deterministic causes (famously declaring that "God doesn't play dice"), and he was not the only one to think so. However, it took until 1957 for an attractive alternative to emerge, when Hugh Everett developed the Many-Worlds Interpretation of Quantum Mechanics, or the MWI, which stands in opposition to Heisenberg and Schrodinger's indeterministic approach.

In the MWI, every time a quantum experiment with multiple possible outcomes is performed, the universe branches to accommodate each outcome.

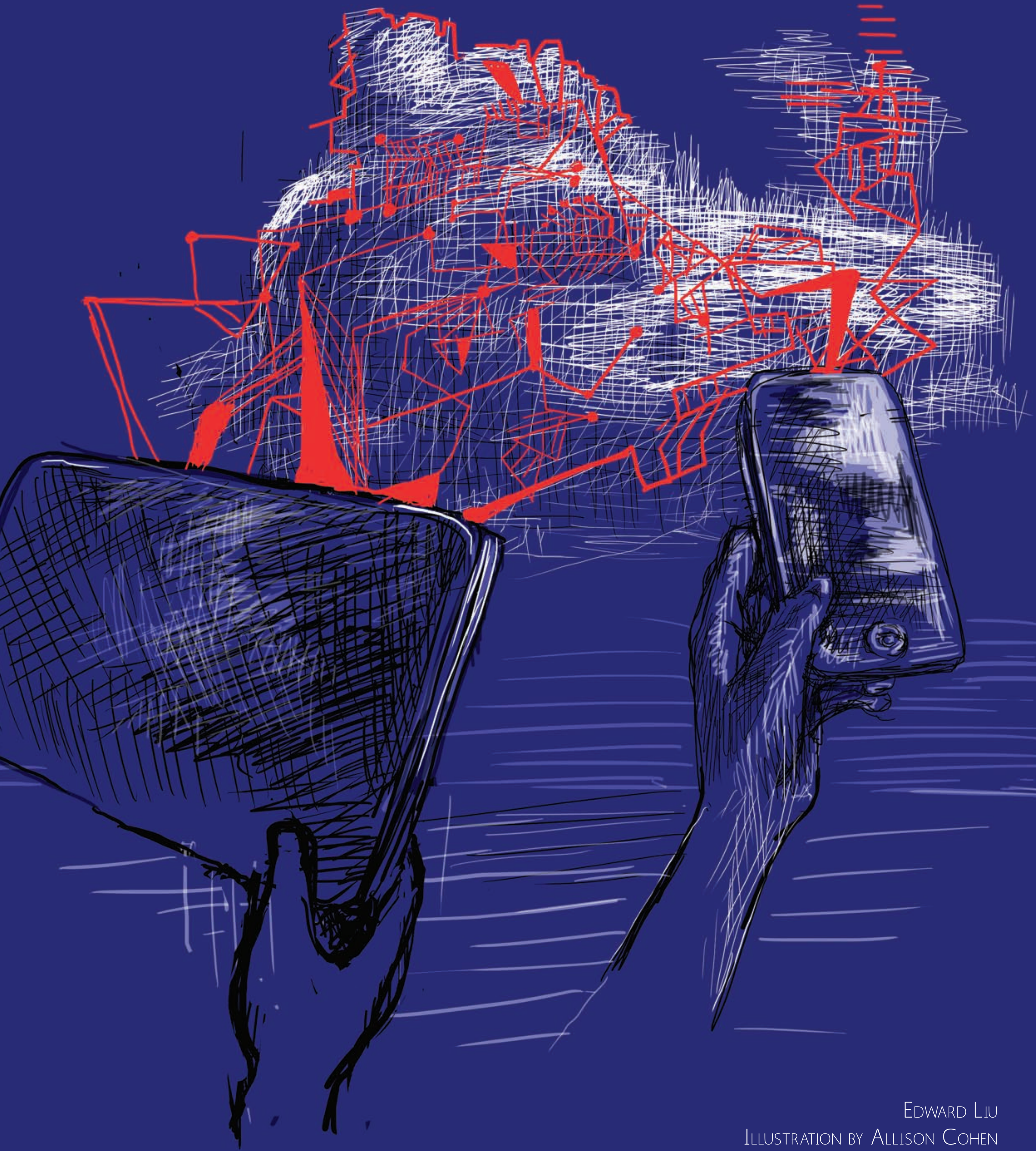
While an observer in one universe measures a quantum state and observes one value, myriad versions of the same observer simultaneously witness all the possible outcomes in different universes. Of course, the observer is unaware of the identical versions of himself in other worlds, as his subjective experience can only be composed of one reality.

The MWI explains how the quantum suicide thought experiment works. Every time the scientist pushes the button, the universe divides in two: one where he lives, and one where he dies. The scientist can only be aware of the universe in which he survives. From his perspective, nothing happens when he presses the button, no matter how many times he does it. If an observer watches the experiment, she is almost certain to see the scientist killed within a few pushes of the button, according to probability. This is because her subjective experience carries over in both parallel realities that split when the quark is measured, as she is alive to see the result in both of them. To her, the scientist has less than a one in one hundred chance of surviving more than seven pushes. From the perspective of the scientist, however, he will see his observer become more and more incredulous as he cheats death over and over again.

It does not require a great leap of imagination to recognize the implications of this experiment. If it is true that there are an almost infinite number of universes, each with its own version of the scientist, and that his subjective experience only carries over in the universes in which he survives, then it follows that from his perspective he should live for the maximum amount of time possible allowed by the laws of physics. Of course, this line of reasoning glosses over the fact that most life-or-death situations are not the result of single quantum events with a limited number of possible outcomes, but rather a chaotic system of limitless interactions. The reasoning also assumes that our subjective experience cannot include death, as that is the end of experience. Still, with an infinite number of possible universes, where all these interactions can play out in an infinite number of ways, there must be at least one in which we are granted quantum immortality, right? In other words, everybody has multiple "experiences" across the parallel realities, but only one experience continues up to the physical limit of the human lifespan (which could very well be forever if every quantum interaction proceeds perfectly). The crux of the thought experiment is that each parallel experience must eventually collapse onto the ones in which the subject is still alive, and possibly ultimately onto one in which the subject is immortal.

So does this mean that within our own subjective experiences we are all going to live forever? It is impossible to say for sure. Hugh Everett, the inventor of the Many-Worlds Interpretation and one of quantum immortality's earliest adherents died at 51, overweight and addicted to cigarettes. But who knows? Perhaps in another universe he lives on. And so might we.

Up in the Cloud



Edward Liu
Illustration by Allison Cohen

The progression of computing efficiency during our post-dot-com era has steadily redefined the way we interact with technology. Recent hardware advancements have allowed for fast communication, data access, and entertainment through cool smartphones, sleek tablets and lightweight netbook computers. While the processing power and memory capacity of these mobile devices are impressive, such improvement is consistent with historical trend—Moore's Law tells us that the number of transistors that can fit on a chip doubles about every two years (higher transistor density allows for faster processing speed and greater computing efficiency). More impressive though is what drives these popular consumer gadgets: massive redesign of data delivery and storage. In response to growing demand by consumers and businesses for fast, mobile processing capability, technology companies like Microsoft, IBM, and Google have invested millions of dollars into researching cloud computing and have generated billions of dollars in revenue from this new computing system.

Cloud computing is often misunderstood and reduced to a buzzword that actually describes many different technologies. Definitions for the term vary widely because ultimately, the "cloud" is an abstraction that can be applied through infinitely many implementations. Essentially, cloud computing aims to deliver computing resources and information over a network like the Internet and replace traditional data storage within hardware. One common application is Software-as-a-Service, in which software clients implement a third party's software infrastructure, and cloud computing is centralized in a computer network that shares computation, data storage, and resources through application servers.

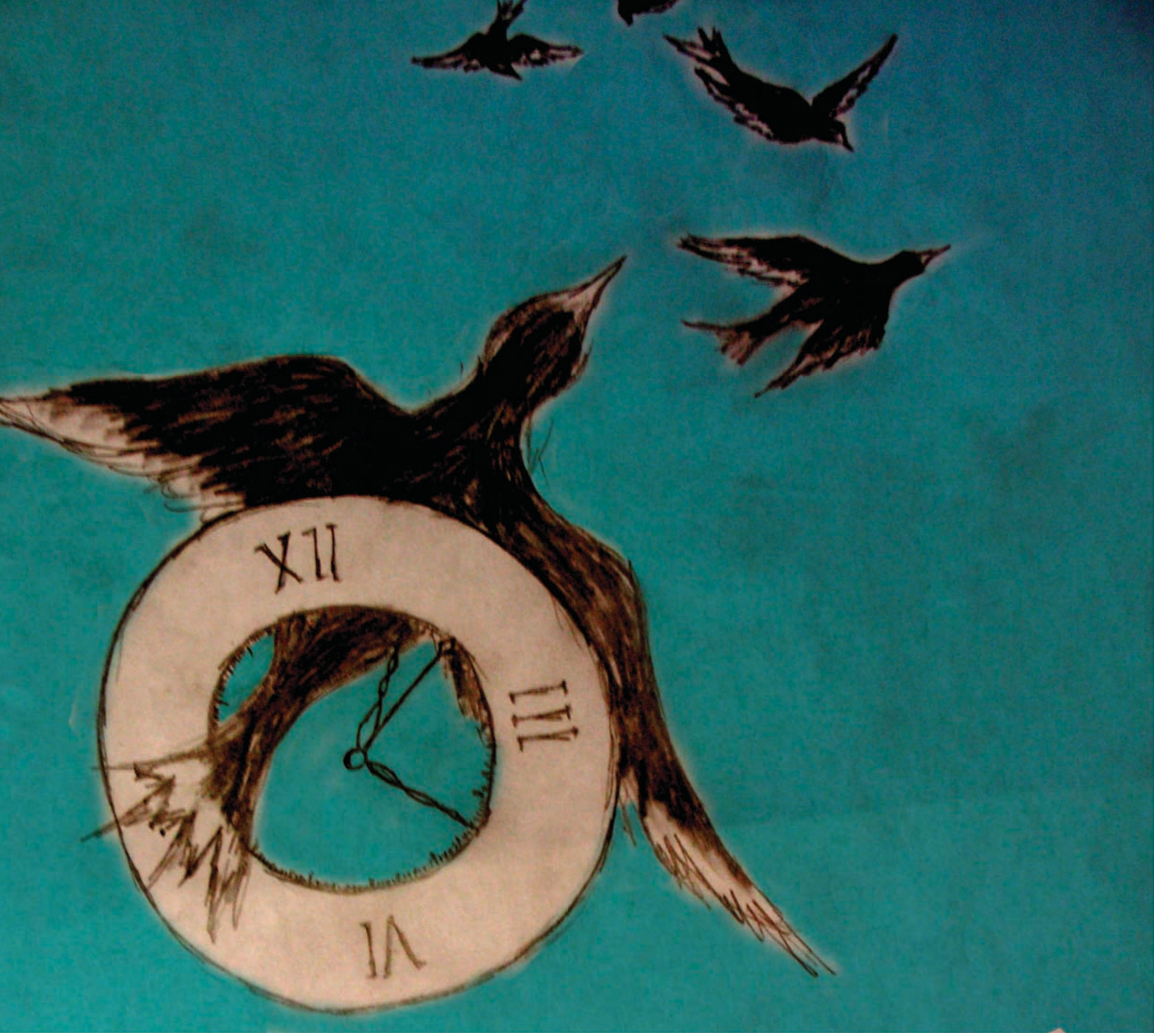
There are many forms of cloud infrastructures, but the general principle is the same: a cloud computing company connects a client computer or network with the company's back-end servers, datacenters, and whatever else is already in the "cloud" of software. This structure is what allows everyday consumers to download and play Angry Birds on their smartphone, share Spotify playlists with Facebook friends, or edit office documents on the go.

Such a system is also vastly more cost-effective and convenient than typical hard grid computing, which is difficult to maintain and synchronize, and also confines data to hardware. Instead, with cloud computing, software distribution becomes much easier to manage and maintain, and companies will no longer need to rent space for large servers or spend resources on IT support. Neither memory nor a large hard drive will be necessary for large computations, which are instead easily done by a cloud company's back-end grid. The improvement in efficiency is so great that the United States government is currently considering reorganizing its IT infrastructure into a Microsoft cloud-based foundation.

Such applications are prevalent in company technology support, but some recently released consumer-targeted electronics also heavily feature cloud computing. The Google Chromebooks, run on Chrome OS, are netbooks stripped down for fast Internet accessibility; boot time is eight seconds, memory is primarily based in Google's cloud storage, and traditional computer software is substituted with cloud-run web applications. It is effortless to go online, access personal files, stream media and collaborate with other users. There are thousands of web applications that can be easily downloaded for free, including Google's well developed office suite and management tools.

Another popular cloud-based gadget is Amazon's new eReader/tablet hybrid, the Kindle Fire. Not only does the Fire store all digital content on Amazon's Elastic Compute Cloud (EC2), it also features a new cloud-accelerated, split-browser architecture called Silk. With each page request, the browser dynamically divides labor between on-board computation and cloud computing, which makes analyzing network conditions, page complexity, storing cache, and conserving battery more efficient. This cloud-powered Silk technology allows for fast web browsing and high-quality media streaming. Both the Chromebook and the Kindle Fire are stepping-stones in the shift from hardware-based computing to cloud computing.

Despite its misconceptions as a common buzzword, cloud computing is driving the advancement of mobile technology and easily accessible data. This service has changed how businesses acquire computational resources and how consumers interact with information and software. Cloud computing has the potential to help integrate the digital world we live in with the physical one around us.



Your Sleeping Patterns Affect Your Health

Yang (Sunny) Li
Illustrations by Esha Maharishi

Many of us have probably experienced waking up to that annoying alarm, pressing snooze a few times, and finally getting out of bed ten minutes later. Or how about when we don't wake up at all and instead sleep through half of our 9am class? Or maybe we're so tired after cramming for midterms that we lay down to nap at 4pm and wake up to find it's already 10pm and then can't fall back asleep again at night? If this happens to you, you may have an abnormal circadian rhythm.

All living organisms, from bacteria to mammals, have an innate biological clock, which regulates their circadian rhythm. The circadian rhythm organizes an organism's behavior and physiology, allowing it to adapt to both night and day. The circadian rhythm establishes recurring events, including the sleep/wake cycle, to occur approximately every 24 hours. Circadian rhythms are affected by both internal and external cues. Exposure to external cues, such as light and varying temperatures, helps set the circadian rhythm (otherwise known as "entraining" the organism). Light is the main cue that helps set an organism's circadian rhythm. Despite this, an organism also has internal clocks that maintain its behavior even when external cues are removed, such as in the case when the organisms are exposed to constant darkness. The "master clock" for mammals is located in the hypothalamus and is known as the suprachiasmatic nucleus (SCN). Scientists working in chronobiology labs, including Dr. Allada at Northwestern University, believe that there are many regulatory clocks within different tissues of the body.

Organisms that have properly functional circadian rhythms have sleep/wake cycles that repeat approximately every 24 hours, with or without external cues (after they have been entrained by environmental cues). Therefore, human beings with "normal" circadian rhythms should be able to wake up and fall asleep at approximately the same time every day, without any external interference. In fact, studies show that when volunteers are placed in caves or special housing units for weeks without clocks or any external time cues (known as "free-running"), they tended to have a sleep-wake pattern that repeats every 25 hours (they wake up and go to sleep one hour later each day). In 2007, researchers at Harvard Medical School found that adults of all ages tend to "free-run" at about 24 hours.

People who don't have this natural circadian rhythm may be subject to various health hazards and decreased immune system responses. Many scientists have studied the health effects of people doing shift work at night. Evidence has accumulated over the last few years that has led the International Agency for Research on Cancer (IARC) to classify shift work as a possible human carcinogen. Studies have shown a strong link between circadian rhythm disruption, due to shift-work (exposure to light at night, etc.) and breast and colon cancer. Clinical studies have looked at women who work night shifts, which disrupt their circadian time structure. These women have a 50% greater chance of breast cancer than the control group of women who do not work night shifts. In 2008, researchers reported in the Journal of the National Cancer Institute that women working at night have the lowest levels of overnight urinary melatonin excretion, a measure of the degree of circadian disruption. These women also have the highest risk of breast cancer compared with women working only in the day and women working in the night who have higher levels of overnight melatonin excretion. This suggests that melatonin, a hormone involved in the human sleep/wake cycle, is a factor in circadian-regulated immunity.

Studies have also explored the genetic factors involved in circadian disruption and immunity. These studies are usually performed on model organisms such as fruit flies or mice. Scientists can disrupt the circadian clock in fruit flies or mice by inhibiting the function of certain circadian clock genes and proteins, including the period gene and protein (PER), the timeless gene and protein (TIM), the clock gene and protein (CLK), and the cycle gene and protein (CYC). In 2009, scientists at the Medical Chronobiology Laboratory published findings that PER1 and PER2, different versions of the period protein, have tumor-suppressing activity. When these genes are disrupted in cancer cells, cancers grow twice as fast as otherwise identical tumor cells both in vitro and in vivo. This supports research done by the same scientists who disrupted the clock gene in mice with cancer tumors, so that when the mice were exposed to even a small amount of light at night, the tumors in these mice grow faster than those in mice without exposure to light at night.

In addition to affecting tumor formation, the circadian rhythm also influences the timing of many infectious outbreaks, especially in the case of inflammatory diseases. For example, heart attacks commonly occur at 8am and asthma attacks at 4am. Current research done in chronobiology labs, including Dr. Shirasu Hiza's lab at Columbia University Medical Center, on Drosophila shows that flies infected with bacterial pathogens at different times of the day exhibit different immune capabilities (as seen by their survival rates). Although strong evidence seems to support the link between circadian rhythm and immunity, there is little understanding of the molecular mechanisms responsible for this. Therefore, the field of circadian rhythm is currently being expanded to explore how scientists and physicians can target different diseases using knowledge about the circadian rhythm.

In the meantime, we should do as much as we can to adjust to a natural 24 hour sleep/wake cycle so that we do not subject ourselves to a greater risk of health problems. To do this, we should aim to sleep and wake up at approximately the same time every day, in order to "entrain" our bodies. We should also make sure that when we sleep, we are exposed to as little light as possible, as light is known to disrupt sleep quality, even if we do not actually perceive it. Other sleep advice: setting aside your bed only for sleep (in other words, no working or reading on your bed), refraining from eating a heavy meal right before bedtime, and refraining from exercising immediately before bedtime. These tips help most people sleep better; however, you should try to find what method suits you best so that you get quality sleep and wake up refreshed, thereby maintaining a proper circadian rhythm.

Illusions: Philosophy, Psychology, and Neuroscience

Dorothy Chen
Illustration by Ashley Lee

The world is one grand illusion." —Anonymous.

Philosophers have argued about this phrase since antiquity. Skeptics since Plato's day have pointed to the disconnect between reality and the world as we perceive it, and thus doubted our capacity for any knowledge of the external world. All Columbia College students periodically encounter different theories of illusion in the course Contemporary Civilization—in the form of Descartes's Evil Genius, Locke's secondary properties, and Kant's phenomenalism. In popular culture, the idea of an illusory world haunts us; the film The Matrix wouldn't have received so much acclaim if we weren't genuinely concerned with the possibility of being brains in vats.

Yet what is so special about the idea of the world as an illusion that prompts us to return to it repeatedly? One possibility is just that we don't like to be tricked. We would like to think that our senses provide us accurate information about the world. Thus, the possibility that they don't frightens us. Consider the classic example of the invisible gorilla experiment. In this University of Illinois psychology study, viewers were asked to watch a video of a basketball game and count the times that the ball was passed between players. Statistically, around half the viewers did not see the man in the gorilla suit who walked slowly across the screen, beat his chest, and then walked away. If viewers could miss an entire gorilla, what else could they miss? It is precisely the possibility for grave human error that scares us and makes perceptual problems so interesting.

Intriguing as these problems are, the amount of philosophical time and effort devoted to trying to solve them is surprising. In a recent lecture, Cambridge professor Tim Crane pointed to what he calls "The Problem of Perception" as created by the phenomena of perceptual illusion and hallucination - how could these kinds of error be possible when, intuitively, perception seems to give us immediate access to reality? If he is right and illusory cases really give rise to the problem of perception, then it seems that any perceptual framework that accounts for illusory cases could solve the problem. Essentially, we could simply explain away illusions using the current scientific model of perception, since we can easily identify the illusory cases and recognize those errors, while preserving the general reliability of our sense. Surely, scientists have already given us such a perceptual framework.

However, the search for a scientific explanations for the disconnect between the perceived reliability of our senses and their intrinsic susceptibility to error is complicated, as Crane's problem of perception is actually scientifically supported. According to Stephen Macknik and Susana Martinez-Conde's article "The Neuroscience of Illusion in Scientific American, "it's a fact of neuroscience that everything we experience is actually a figment of our imagination," since the same physical machinery in the brain is responsible for both our genuine perceptions and illusory experiences such as dreams, delusions, and hallucinations. This means that although in genuine perception there is a correct sensory input (i.e. what we experience matches what is actually out there), in illusory cases there is not, and the actual physical state our brains is indistinguishable between the two scenarios.

What other factors can account for the difference between genuine perception and illusion, if not dissimilarity in brain chemistry? One popular approach is to distinguish genuine perception as that which holds the correct relationship between the physical reality and one's subjective perception of it. Consequently, illusions are merely cases where the subjective perception is disassociated from what is actually there, for instance, seeing something that is not there or something different from what is there. Intuitively, this makes sense as we can only correctly perceive what is actually there; otherwise, we must have made an error.

As convincing as this account sounds, it does not explain all illusory cases. Consider veridical hallucination, in which perception happens to correspond to reality. For example, suppose you are hallucinating that a pig standing before you, but by chance there happens to be a pig in front of you that is exactly identical to the one you are hallucinating. In this case, do you genuinely perceive the pig? Surely you can't be, given the premise that you are hallucinating. Yet the physical reality is not disassociated from your subjective perception since your hallucination matches what is actually there, so by the account above, this is a case of genuine perception. Either way, this case generates a dilemma.

Scientists and philosophers have different ways of explaining this case, but it is enough for our purposes here to realize that the problem of perception is more complicated than one would initially think. The difficulties presented by illusory cases are genuine ones worthy of investigation.

Unfortunately, illusions are far from a central topic of scientific discourse, and those who study them are often pushed to the sidelines. As Swedish neuroscientist Henrik Ehrsson, one of the world's foremost experts on physical illusions, admits, "The other neuroscientists think we [who study illusions] are a little crazy." Ehrsson initially got into the science of illusions after becoming intrigued by the rubber-hand illusion, a trick devised by American researchers in the nineties. In this classic psychology experiment, researchers seated each subject and placed their left hand atop a small table. Then, a standing screen hid the arm from the subject's view, after which a life-sized model of a rubber hand and arm was placed on the table directly in front of the subject. Researchers asked the subject to focus on the rubber hand while they stroked both the artificial hand (in view) and the subject's hidden left hand using small paint brushes, synchronizing the strokes as much as possible. After ten minutes, subjects indicated that they felt the touch not of the hidden brush but of the viewed brush, as if the rubber hand as sensed the brush. Through this experiment, researchers have come to realize that our sense of self is not as attached to our ownership of the body as previously thought.

Using the same principle used in the rubber hand illusion, Ehrsson over the years was able to devise more surprising tricks, such as inducing his subjects to falsely believe that their entire body was shrinking, or that they owned a third arm. He was even featured in a recent issue of Nature as a master of illusion with the power to give people out-of-body experiences. The writer of that article, Ed Yong, purportedly felt what it was like to be "separated from your body and then stabbed in the chest with a kitchen knife."

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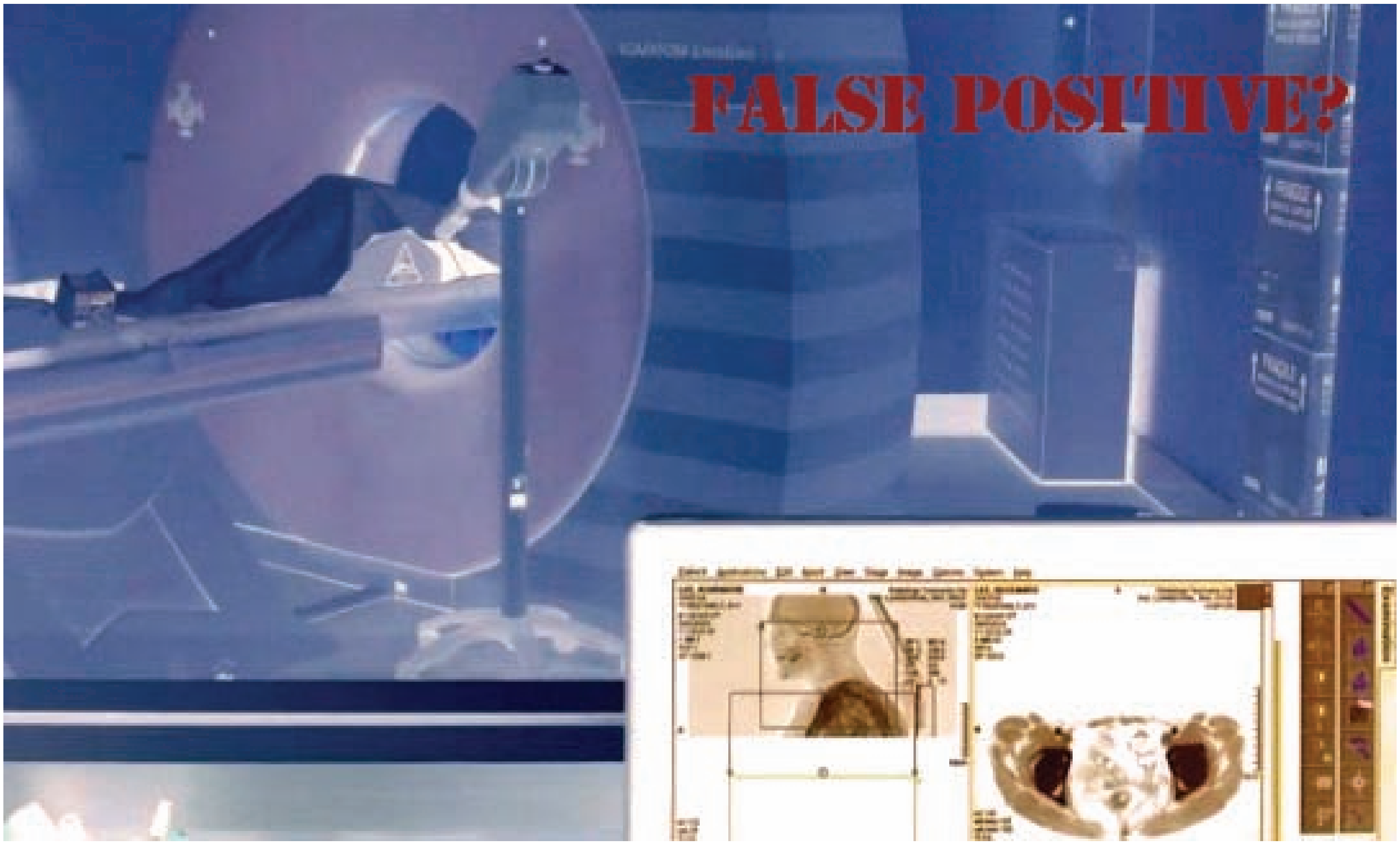

Screening That Saves Lives:
Recent Study Shows Low-dose Computed Tomography (CT) Lung Cancer Screening Reduces Mortality

In the United States, lung cancer remains responsible for the highest number of cancer deaths. Each year, it causes more deaths than breast, colon, lymph, ovarian and prostate cancers combined. According to the United States Cancer Statistics (USCS) Working Group, 203,536 people were diagnosed with lung cancer in the United States in 2007. Of those diagnosed, 158,683 people died from lung cancer.

Wouldn't it seem intuitive that screening for lung cancer decreases deaths? Surprisingly, prior studies failed to demonstrate the benefit of regular screening for lung cancer. Randomized, controlled trials using chest x-rays and sputum cytology—in which mucus from the lungs is inspected under a microscope—in the 1970s and 1980s did not confirm lung cancer screening as particularly effective. In fact, the American College of Chest Physicians (ACCP) concluded in 2007 that, "For high-risk populations, no [lung cancer] screening modality has been shown to alter mortality outcomes." There was little evidence-based medicine to support

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Illustration by Evelyn Warner

screening, until now. A groundbreaking National Lung Cancer Screening Trial (NLST), published in the August 2011 edition of the New England Journal of Medicine shows that screening high-risk patients with low-dose computed tomography (CT) reduces mortality by 20%.

The National Cancer Institute (NCI) funded study was conducted between 2002 and 2010. It compared the utility of low-dose computed tomography (CT)—a high-tech, cross-sectional x-ray of the internal structures of the body—with the utility of chest x-ray in screening for lung cancer. At 33 medical institutions across the nation, patients between the ages of 55 and 74 years with cigarette smoking histories of 30-pack years were enrolled between August 2002 and April 2004. A total of 53,454 patients participated—approximately half of whom were randomized to screening with low-dose CT, and the other half to screening with chest x-ray. They received annual screening for 3 years, and the research team collected data about lung cancer cases and deaths until December 2009.

A significant percentage of the results were false-positives—96.4% in the low-dose CT group and 94.5% in the chest x-ray group—indicating that both screening methods were overly sensitive. But the trial had striking outcomes: CT detected more cases of lung cancer at earlier stages, and reduced the number of deaths. The rates of death from lung cancer in the CT and x-ray groups were 247 and 309 deaths per 100,000 persons per year respectively. These results indicated a 20% reduction in lung cancer deaths with CT screening.

But, of course, every study raises controversial questions. Could false-positive results lead to additional patient tests and potential patient injury? Do the benefits of CT screening outweigh the radiation exposure and the theoretical risk of radiation-induced cancers? Given the high cost of medical care in the United States, can society bear the high cost of CT lung cancer screening? These issues have to be considered.

That being said, this trial is highly noteworthy as it is the first to document the benefit of screening for lung cancer. As a matter of fact, the study was terminated early due to overwhelming positive results. This tool could be incredibly valuable in revolutionizing lung cancer diagnosis and in saving lives.

Is this Real Life?

Alyssa Ehrlich
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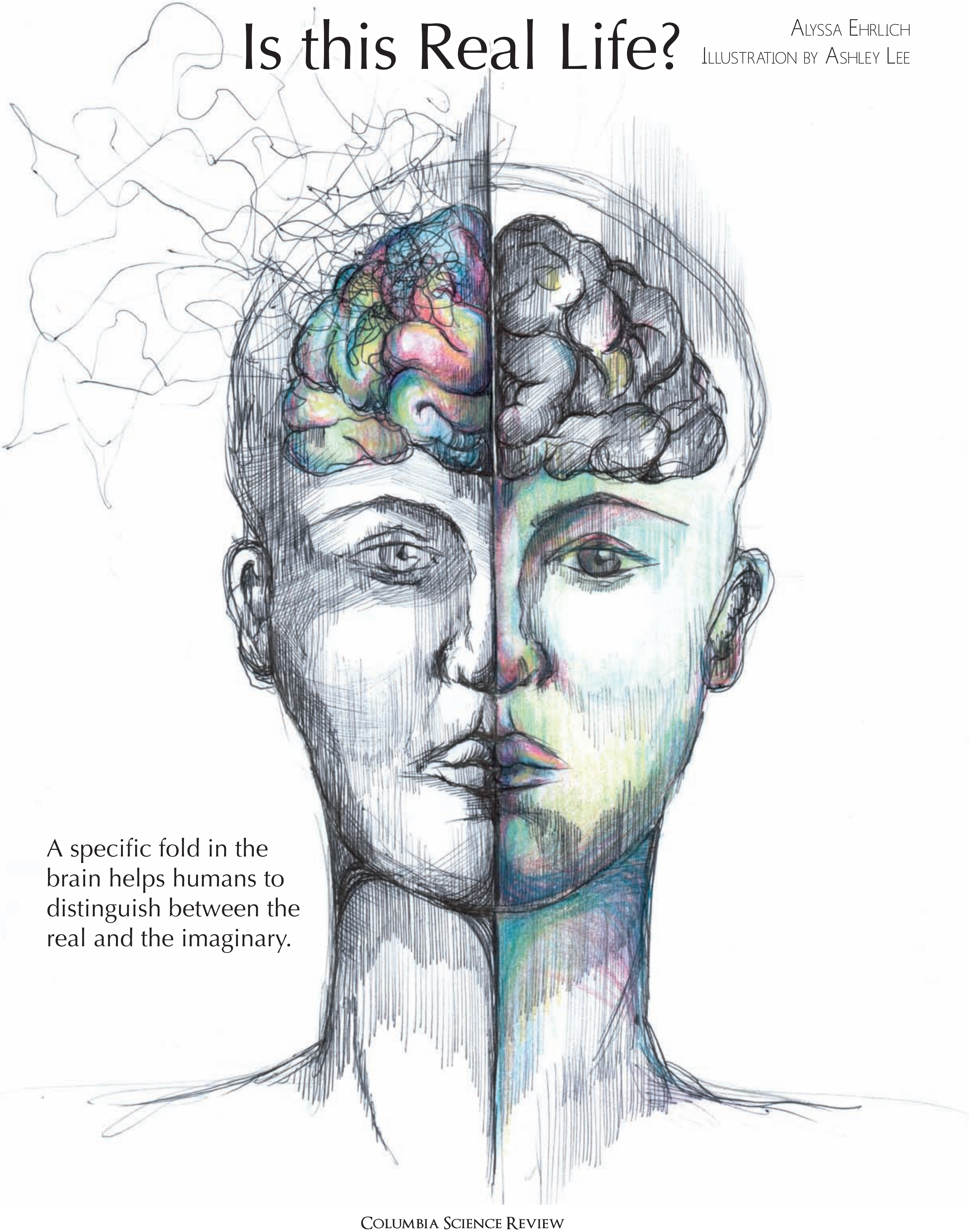


A specific fold in the brain helps humans to distinguish between the real and the imaginary.

Assuming you had Internet access in 2009, you've probably seen the YouTube video "David After Dentist." Featuring a very disoriented 7-year-old David on the car ride home from a tooth extraction, the video captures the boy's bizarre conversation with his none-too-concerned father. Amidst a series of hilarious outbursts, David posits a philosophical gem that is by far the most popular catchphrase spawned by the viral video: "Is this real life?" he asks. While David was clearly suffering from the temporary aftereffects of anesthesia, some people actually find it difficult to differentiate what is real life from what isn't, even when they are not under the influence of any confusion-inducing substance.

The existence of a newly discovered brain abnormality may explain why certain people have trouble accurately recognizing reality. In a recent study, researchers at the University of Cambridge found that the absence of a particular fissure in the surface of the brain—called the paracingulate sulcus—correlates with relatively poorer performance on tests of the cognitive faculty known as "reality monitoring." Reality monitoring is defined as the ability to accurately distinguish between information generated by internal mental processes and that perceived from external surroundings. In this manner, reality monitoring allows us to define reality by separating memories of events that we have actually experienced from memories of our own thoughts, dreams or imaginings.

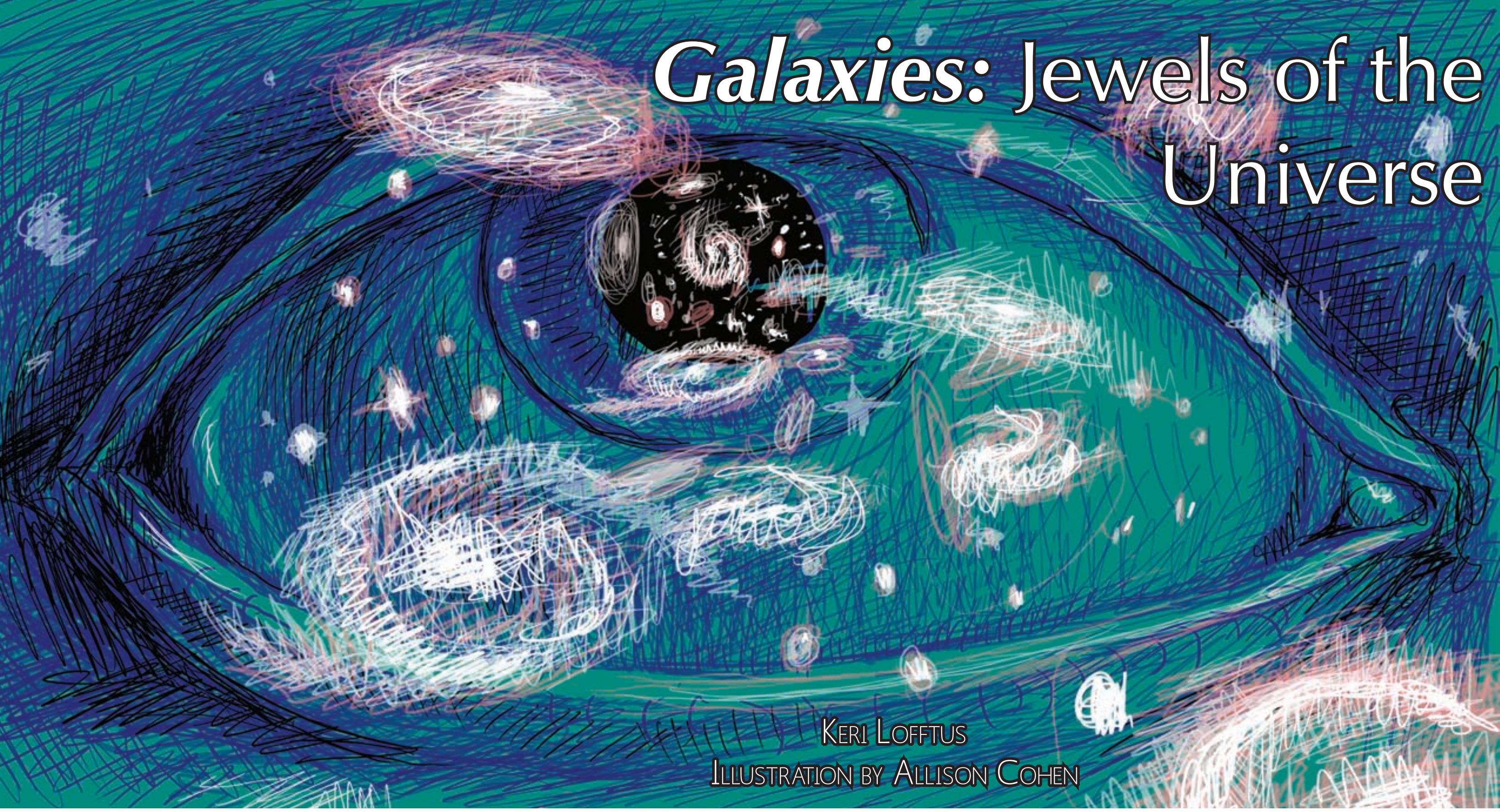
The size of the paracingulate sulcus, or PCS, varies considerably among otherwise normal individuals. This is possibly explained by the fact that the PCS is one of the last sulci to develop prior to birth. Consequently small differences in the length of a fetus' gestational period could dramatically affect the degree to which this structural fold develops in its brain. In fact, it is estimated that the PCS may only be visible in 30-60% of the normal population. In the Cambridge study, fifty-three healthy volunteers were recruited to participate based on the distinct presence or absence of a PCS in either side of his or her brain, as revealed in MRI scans. Participants were presented with one of two visual or auditory stimuli, either a complete familiar word pair (e.g. "Yin and Yang") or the first term in such a word pair followed by a question mark or pause (e.g. Yin and ?); the former condition constitutes perception, while the latter condition is meant to induce imagination. In order to test reality monitoring ability, the participants were later asked to report whether they had actually perceived the second word of the pair or if they had just imagined it. Those participants without a PCS in either hemisphere performed significantly worse in the reality monitoring task for both auditory and visual stimuli, suggesting a relationship between a common anatomical feature and a specific cognitive impairment.

Even more remarkably, subjects without a PCS were statistically just as confident in their reality monitoring ability as the rest of the participants, despite that fact that those without a PCS had a clearly diminished capacity to differentiate between real and imaginary stimuli. These results suggest that people without a PCS are likely unaware of any deficits they may have in reality monitoring, an impairment which might lead to problems in their day-to-day lives. Have you ever neglected to lock a door because you imagined that you had already locked it? Or perhaps insisted you heard someone say your name in a crowded room, when in fact no one said anything? If you have, you can see how these sorts of incidents, which are the result of a failure to properly monitor reality, would be quite troublesome to deal with on a daily basis, especially if you had no idea why you were experiencing them.

Research on the PCS also has implications for the understanding and treatment of certain psychiatric conditions, particularly schizophrenia. Schizophrenia, which literally means, "a splitting of the mind," is a condition in which the patient completely loses touch with reality. Another way to frame schizophrenia is to view it as a severe impairment of the reality monitoring system. The paranoid schizophrenic, who adamantly believes that his auditory hallucinations are actual sensory experiences, might actually be suffering from an extreme case of reality monitoring dysfunction. Unsurprisingly, several earlier studies have found a greater incidence rate of reduced PCS size among schizophrenic patients. However, the fact that many people without a PCS remain mentally healthy, while some with the fold present in both hemispheres are diagnosed as schizophrenic, stresses the multifaceted nature of the disorder. This complexity precludes reality monitoring dysfunction as a comprehensive causal explanation for schizophrenia.

While it has been established that the PCS clearly has a role in reality monitoring, researchers have yet to determine the exact physiological mechanism by which the fold affects neural processes. One possibility put forth by the Cambridge study authors is that the absence of PCS is the result of an increased volume of gray matter; in other words, an excess of neuronal cell bodies fills in the gap where the sulcus would normally be. As a result, these extra neurons somehow interfere with the normal functioning of reality monitoring. Whatever the morphological cause, suffice it to say that even as you read the words of this article, your brain is constantly asking, "Is this real life?" and your paracingulate sulcus—if you have one—answers back just like David's Dad, affirming that yes, this is real life.

Galaxies: Jewels of the Universe



Keri Lofftus
Illustration by Allison Cohen

When the ancient Greeks gazed up at the night sky, they could not help but notice the enormous arc of dense stars interspersed with cloud-like dark patches, which stretched from horizon to horizon. They named it "galaksias" (from which we get the modern English word "galaxy") which translates to "milky circle" (from which the name of our galaxy, the Milky Way, is derived).

For the majority of human history, the Milky Way was thought to be the only galaxy that existed. In spite of this, other galaxies were observed and cataloged. Andromeda, the closest major galaxy to our own, can be seen with the naked eye, and references to it have been discovered in astronomical catalogs over 1,000 years old. With the invention of the telescope in the early 1600's, many more galaxies were located. In 1774, French astronomer Charles Messier first published his famous Catalogue of Nebulae and Star Clusters, an inventory of deep-sky objects, which are permanent objects in the sky, unlike the moving asteroids and comets, but are not stars or one of the eight planets orbiting our Sun. Eventually, this catalogue grew to contain 109 items, 39 of which we now recognize as galaxies, but which Messier labeled as nebulae.

During the next 150 years, some did speculate that certain nebulae were actually systems outside of and extremely distant from the Milky Way, including the German philosopher Immanuel Kant, who called them "island universes". In 1920, astronomers Heber Curtis and Harlow Shapley held what is now known as the Great Debate, where they argued about the nature of the so-called island universes and the size of the universe. Curtis believed that the Andromeda "nebula" was an independent galaxy because its fuzzy spiral contours mirrored the dark dust clouds of the Milky Way. Over the next two years, astronomers Ernst Öpik and Edwin Hubble each estimated the distance to the Andromeda nebula and determined that Andromeda was too distant to be a component of the Milky Way.

Since then, astronomers have studied galaxies intently, allowing them to gain a greater understanding of the different types of galaxies. Galaxies are the basic building blocks of large-scale structure in the universe Today, astronomers estimate that the universe contains about 150-200 billion galaxies. Galaxies are made up of stars, dust, gas, and enormous amounts of dark matter, a substance which does not absorb or reflect any electromagnetic radiation, but nevertheless interacts strongly with the stars, gas, and dust via gravity. Approximately 85% of all matter in the universe is dark matter, with the remaining 15% being baryonic, or "normal", matter. A galaxy's dark matter tends to exist in a large, invisible halo around the visible part of the galaxy. Most galaxies also have a supermassive black hole at their center.

Galaxies are not spread evenly across the universe, but exist in clusters. Clusters can be as small as just a couple dozen galaxies or as big as 1,000 galaxies. The Milky Way is part of a cluster of about 50 galaxies called the Local Group. Groups of clusters are called superclusters. The Local Group is part of the Virgo Supercluster. Groups of superclusters form the largest structures in the universe, called filaments. In between separate filaments are voids, where almost no galaxies exist.

Despite being composed of similar materials, not all galaxies are alike. There are four main types of galaxies: elliptical, spiral, lenticular, and irregular.

Elliptical galaxies are unique in that they possess only minute amounts of gas or dust; they are therefore unable to make new stars. Instead, elliptical galaxies consist primarily of small, older stars. The size of elliptical galaxies is highly variable, with both the largest and some of the smallest galaxies currently known being ellipticals. Smaller ellipticals are designated dwarf ellipticals. Their name is suggestive of their shape: an ellipse. They are classified as an "E" followed by a number ranging from 0-7: 0 indicating an ellipse that is almost completely spherical to 7 indicating an ellipse that is extremely elongated, like a cigar. E3 is the most common. Almost all ellipticals have a supermassive black hole at their center. Elliptical galaxies are often found at the center of galaxy clusters and account for approximately 60% of galaxies in the universe.

Spiral galaxies make up roughly 20% of all galaxies in the universe. Their distinguishing feature is a disk containing immense lanes of gas and dust which form a spiral pattern and trigger the formation of multitudes of hot, young, blue stars. A spiral galaxy will also contain a central bulge with a large concentration of stars, as well as a faint halo of stars entirely surrounding both the disk and the central bulge. Just like elliptical galaxies, they usually harbor a supermassive black hole at their centers. There are three main types of spiral galaxies, based on the morphology of the spiral arms: flocculent (which have many short, fragmented spiral arms and make up 30% of spirals), grand design (which have two prominent spiral arms and make up approximately 10% of spirals), and multi-armed (which, as the name suggests, have several well-formed spiral arms). Spiral galaxies of all three types can also have a central bar emanating from the central bulge.

All spiral galaxies are denoted by an "S". They are then further classified by the tightness of their spiral arms (or, in the case of a flocculent spiral galaxy, the tightness of the spiral pattern). Spiral arm tightness is denoted by using one or two of the letters "a" through "d", with "a" designating extremely tight arms and "d" designating extremely loose arms. Within clusters, spiral galaxies are rarely located at the center, but instead are found closer to the edges.

Our galaxy, the Milky Way, the second largest galaxy in the Local Group, has four intermediately loose arms (type Sbc) and a central bar. Within the Local Group, there are two other spiral galaxies. Andromeda, the largest galaxy in the Local Group, is a type Sb, meaning its arms are slightly tighter than the Milky Way's. Triangulum, the third largest in the Local Group, is a type Scd, meaning its arms are slightly looser than the Milky Way's.

Lenticular galaxies are galaxies that are intermediate between ellipticals and spirals. Like spiral galaxies, they have disks containing gas and dust, but in much smaller quantities. These disks can sometimes manifest a slight spiral structure, but nothing like the vast and organized spirals of spiral galaxies. Also like spiral galaxies, lenticular galaxies have a central bulge, but it is much larger, giving lenticulars a spherical shape comparable to elliptical galaxies. Their stellar populations are also similar to elliptical galaxies: old, small stars with little to no formation of new stars. Lenticular galaxies are denoted by an "S0".

Irregular galaxies are the fourth main type of galaxy. As their name suggests, they have no regular structure. Irregular galaxies account for about 25% of galaxies and they tend to be smaller than many elliptical and spiral galaxies. Like spiral galaxies, irregular galaxies tend to include large amounts of gas and dust, which generates an abundance of hot, young stars. Astronomers currently theorize that most irregular galaxies were once spiral or elliptical galaxies that have been distorted by gravitational interactions with other nearby galaxies. Within clusters, irregular galaxies often orbit around the more massive ellipticals and spirals as satellite galaxies. They are designated "Irr".

Galaxies do not remain unchanged throughout their lifetimes. Since galaxies are located within clusters, it is inevitable that they will interact with each other. When two galaxies closely approach one another, their structures can be distorted. As mentioned above, this is how astronomers believe irregular galaxies are formed. However, galaxies can also collide with each other. In a galaxy collision, it is immensely unlikely that any stars will crash together, but the gravitational interactions will cause many stars to change their orbits. Some will be thrown out of their galaxy entirely, while others might be thrown inward, to be devoured by one of the two supermassive black holes now at the center. All the chaos will cause a sharp increase in the rate of star formation, which causes the now combined galaxies to consume their gas and dust extraordinarily quickly. Soon after, all the gas and dust will be exhausted, resulting in a giant elliptical galaxy.

This is the possible fate of the Milky Way. The Andromeda galaxy is rushing towards the Milky Way at 120 km/s. In roughly 4 to 5 billion years, the two galaxies will make their closest approach, perhaps colliding and, eventually, coalescing into a large elliptical galaxy. Despite the incredible changes this would produce in both the Milky Way and Andromeda, our own solar system is likely to remain unaffected. However, by the time this galactic collision is set to occur, our Sun will have depleted its hydrogen fuel, turning into a red giant star and thus extinguishing any remaining life on Earth.

ILLUSIONS *(Continued from page 17)*

However, these illusory tricks are not mere curiosities that have only entertainment value. Ehrsson is currently working to improve his illusory tricks in order to make artificial limbs more effective. When amputees are given replacement limbs, they are often still consciously aware of the absence of their original limbs, and as a result cannot accept the artificial limb as their own. Ehrsson tries to solve this problem through an adaptation version of the rubber hand illusion. He stimulates small spots on the stump of amputees' former limbs that trigger the feeling of phantom fingers, and at the same time strokes the corresponding parts of a robotic hand. So far, he has been able to convince these subjects that they own the metal limb for up to 15 seconds after the stroking stopped. The next step is to figure out a way to maintain this illusion of ownership for a longer period.

This is just one example where illusions, if understood better by researchers, could have important practical applications. Just imagine how much more accurate robotic maneuvers could become if controllers are tricked into thinking that the robot's body is actually their own. Furthermore, it could lead to wide-ranging applications in fields such as medicine (microscopic robots that perform surgeries within patients' bodies) or defense (to disarm bombs or nuclear devices). The possibilities are endless. Instead of being intimidated by illusions or dismissing them as mere curiosities confined to the realm of philosophy, we can use them to our advantage.

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