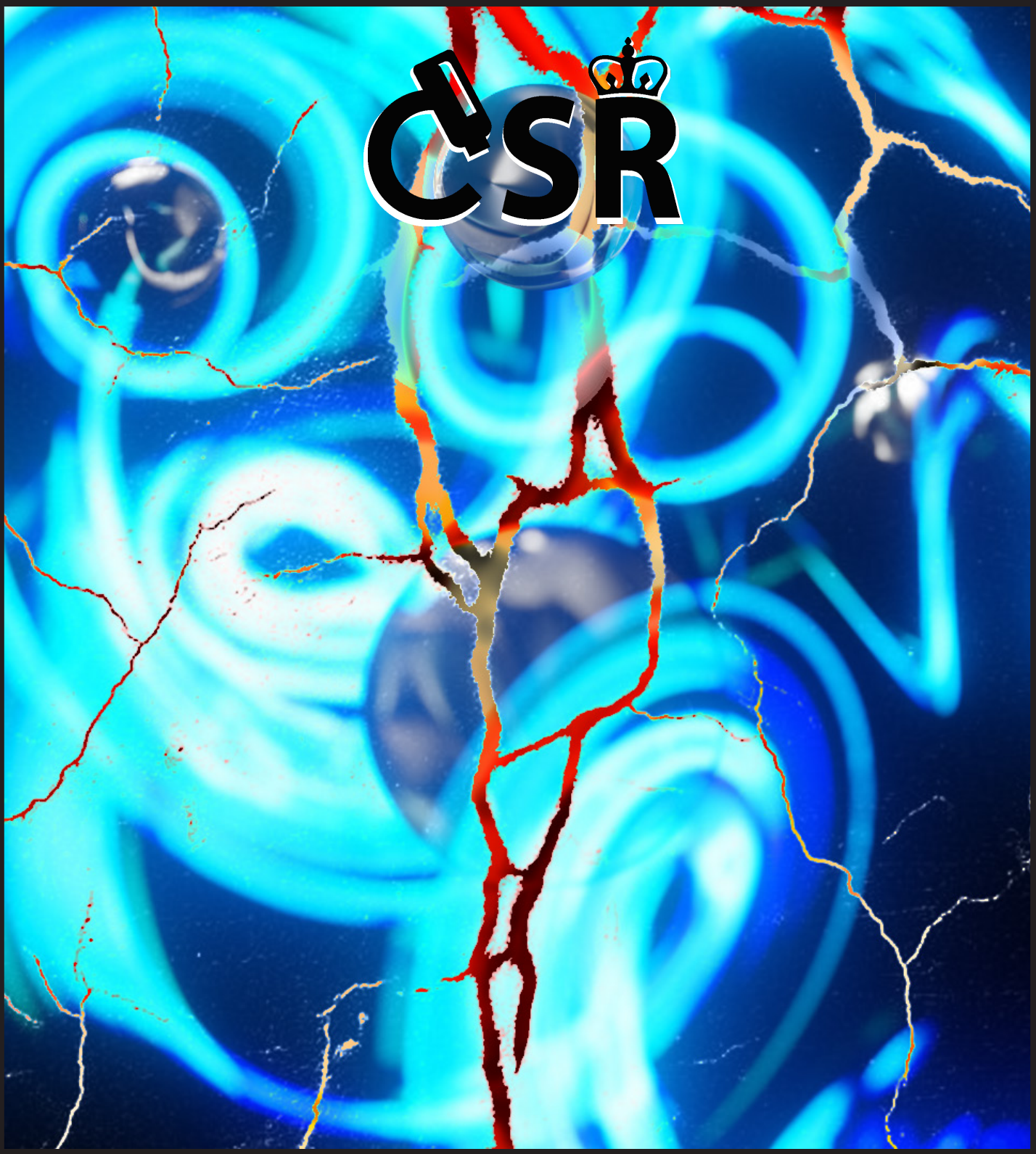

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FROM THE

Dear Reader,

Hello and welcome to the Columbia Science Review's Dear Reader,

It is my pleasure to welcome you to the Columbia Science Review's Fall 2021 print issue! As we all adjust back to a more in-person life following our virtual semesters, I cannot thank our tireless writers, editors, illustrators, and layout editors enough for their hard work and dedication to not only scientific knowledge itself, but also the equitable and intelligible dissemination of that knowledge in pursuit of the public good.

While we all wish for a post-pandemic world to arrive as quickly as possible, COVID-19 and its effects on society still loom over our heads. Thus, to try to balance the still-present issues of COVID-19 with other scientific discoveries, articles from this edition cover topics ranging from vaccine equity to how science fiction drives scientific progress. Each of the topics presented in this edition greatly excite me, and I hope that you enjoy reading and learning from the articles as much as I have.

This is my final year on the Columbia Science Review, which I've been a part of since my freshman year. This club has been one of the most impactful and influential parts of my undergraduate experience, and it's made me a more curious, resilient, and collaborative individual. The memories I've made and the experiences I've had through the Columbia Science Review working with my fellow members in pursuit of our common mission are unforgettable, and I'll certainly treasure them in the years to come.

Sincerely,

Linghao Kong
Editor-in-Chief

EDITORS

Dear Reader,

Welcome to the Fall 2021 print issue of the Columbia Science Review! I hope you enjoy reading it just as much as we did creating it and that your interest and imagination are captured by articles ranging from science fiction and space travel to deconstructing theories of physics and brain computer interfaces.

This issue takes on more abstract and whimsical areas of scientific research. We toy with questions, thought experiments, and hope to show the value of creativity in science. At the same time, staying grounded we explore scientific research especially relevant at the present moment looking at the landscape of vaccine distribution and the aftermath of COVID-19. Whatever piques your interest we have it for you.

Despite all of the challenges with coming back to an in person format this past year, I am incredibly thankful for our writers, editors, illustrators, and layout designers who have come together to make an issue that speaks to each of their passions. In doing so they allow each of us to join along for the journey as we traverse through many spaces and dimensions of scientific research that are developing in the coming age. I am so grateful to be part of a community filled with such dedicated, hard working, and inspired individuals. We hope that you get a glimpse into that in our Fall issue you are about to embark on.

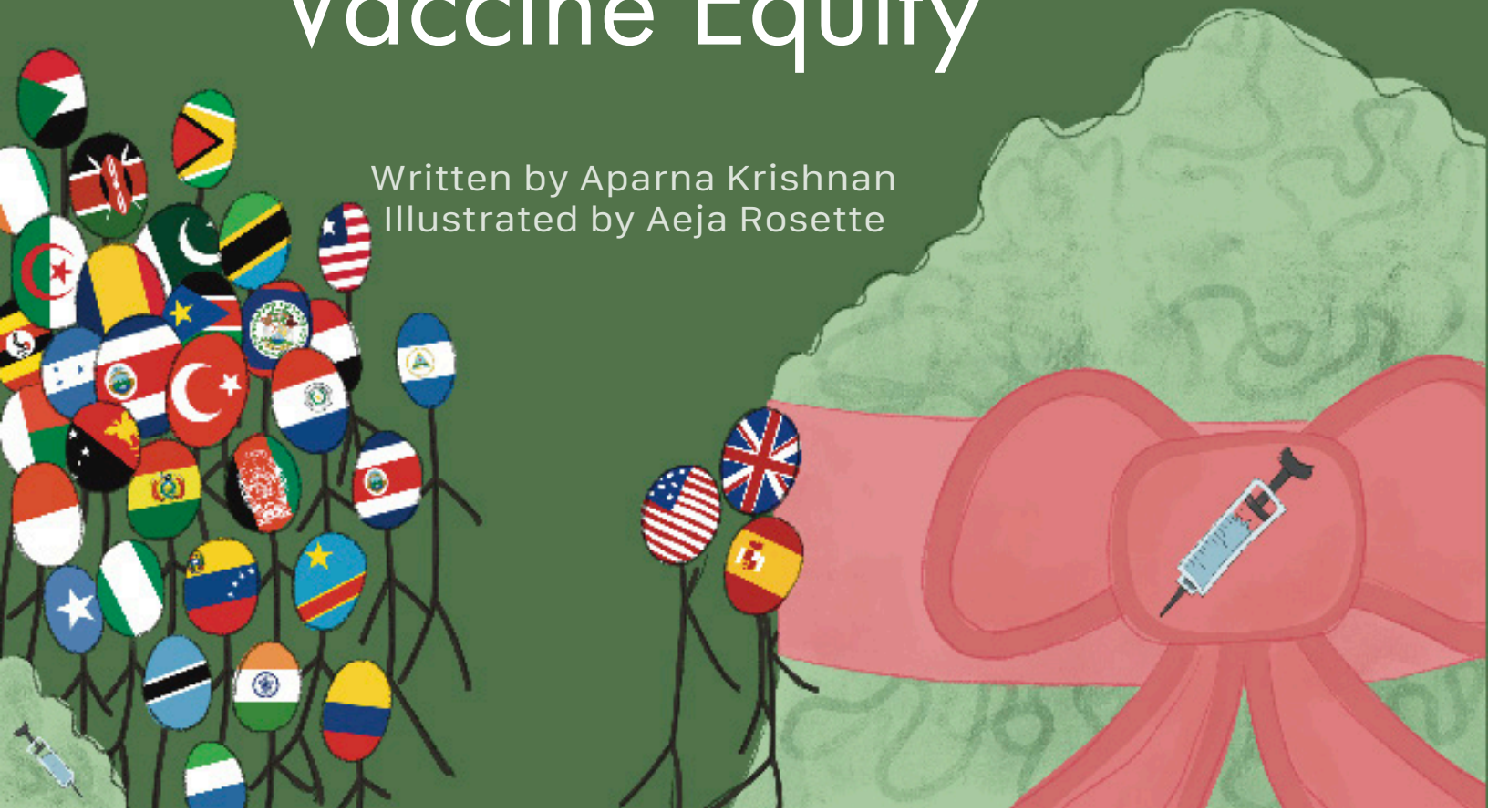
Thank you so much for taking the time to read some of the amazing work put together by our talented team! Dive into the pieces and topics we explore in this issue. I know many of them left me with a completely different shift in perspective. I fell in love with science for its ability to dramatically shape the way I look at the world around me, and I know that these articles will do just that!

Sincreley,

Aida Razavilar
Managing Editor

The Race Toward Global COVID-19 Vaccine Equity

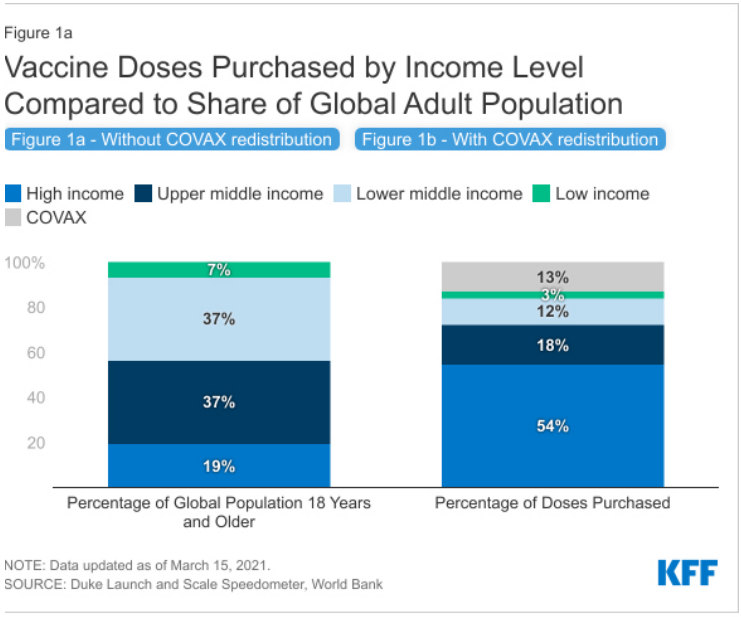
Written by Aparna Krishnan
Illustrated by Aeja Rosette



According to the UK's Economist Intelligence Unit (EIU) [1], more than 85 poor countries will not have widespread access [2] to COVID-19 vaccines before 2023, if at all.

Starting early 2021, vaccines developed by Pfizer (US)-BioNTech (Germany), Moderna (US) and AstraZeneca-Oxford University (UK) have been deployed to treat the SARS-CoV-2 virus — the cause of the COVID-19 pandemic which began in December 2019. Wealthy nations such as the US, UK, and members of the EU have seen a massive vaccine roll-out in just a few months; the US has delivered more than 100 million first doses [3] and the UK more than 30 million [4]. These leading developed nations will likely see economic growth starting mid-2021, provided that vaccination continues to accelerate and the public is largely protected from the newly emerging SARS-CoV-2 variants [5]. In fact, The Guardian forecasts that the US will see the most improvement [6] of the leading nations, "in part due to the planned $1.9 trillion of tax cuts and spending increases that form the centerpiece of [President] Joe Biden's economic recovery plan."

Figure 1a



However, while the countries at the front of the line for vaccines are experiencing gradual economic re-openings, nearly 45% of countries are expected to remain unvaccinated until mid-2022 to 2023 [2]. The latest data from the Duke Global Health Innovation Center Launch and Scale Speedometer [7], which monitors countries' COVID-19 vaccine purchases, shows that "high-income countries already own more than half [8] of all global doses purchased." The US is expected to acquire a total of 1.3 billion [9] vaccine doses, more than three times its adult population. In contrast, some middle-income and most low-income countries will rely on COVAX [10], a WHO initiative aiming to deliver "at least 2 billion doses by the end of the year, including at least 1.3 billion doses to 92 lower income economies." However, these supplies may be slow to arrive [2], conditional on whether any production or delivery issues arise in the richer countries. The figure below (last updated March 15, 2021 by the Duke Launch and Scale Speedometer [7] and the World Bank [11]) shows the vaccine doses purchased by income level compared to its respective global adult population:

As the figure demonstrates, despite lower middle income countries having double the percentage of adults than in high income countries (37% and 19%, respectively), high income countries have purchased more than four times the number of doses (12% and 54%, respectively) [8]. High-income countries have purchased so many vaccines that they now "own enough doses to vaccinate more than twice their populations [8] while low and middle-income countries (LMICs) can only cover one-third," also according to the Duke Launch and Scale Speedometer and World Bank. The repercussions of this global inequality are worrisome. One concern is that, without a more equalized vaccine distribution, the goal to immunize approximately 60% to 72% [12] of the world population to attain herd immunity will continue to be delayed. Agathe Demarais, the EIU Global Forecasting Director, also worries [2] that some of these LMICs, after a two-year waiting period, "may well lose the motivation to distribute vaccines, especially if the disease has spread widely or if the associated costs prove too high." She adds that, "many people in poorer countries remain unable to get access to [vaccines against polio or tuberculosis which have been available for decades]. What was termed a 'novel coronavirus' only one year ago will be with us for the long term, alongside the many other diseases that have shaped life over the centuries."

This forecasted loss of motivation among some middle and low-income countries calls for efforts to lessen the disparities between countries' income levels and their purchased vaccines — mainly via vaccine redistribution. Carlos Del Rio, professor of medicine and global health at Emory University, urges [9] the US to step in and be a leader in the global health arena: "It's in the interest of the United States to start becoming a vaccine supplier to poorer countries. Other countries [like Russia, China, and India] are seizing opportunities to build goodwill and influence globally, while the United States is still focusing internally on vaccinating its own citizens." While the US, along with France and the UK, have stated [8] that they will donate excess doses once their populations have been fully accounted for, this promise is dependent on the robustness of the vaccines against SARS-CoV-2 and its variants as well as how quickly the doses continue to be manufactured and deployed without error.

Another hopeful avenue is the approval of current vaccine candidates [8] in clinical trials. As of April 2021, there are 60 candidates [13] in development, which could potentially boost LMICs' vaccination rates with increased production of doses. However, countries must instill the appropriate infrastructure to produce them in addition to the already authorized vaccines, such as Pfizer-BioNTech or Moderna. Balancing leading nations' own agenda to protect their citizens against their ethical duty to help other countries has proven a difficult task thus far, but it is important that they continue to be held to these standards in order to address the shocking global health inequalities that have come to light during this pandemic.

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Can **Space Travel** Be Considered a **Fountain of Youth?**

Written by Sarah Boyd
Illustrated by Kate Steiner

Avid fans of sci-fi may recall time dilation as a popular concept at play in several novels such as Ender's Game. According to Einstein's special theory of relativity [1], gravitational time dilation is the slowing down of time in a system, relative to an outside observer, as the system approaches the speed of light. This effect is a result of the curved nature of space-time [2] and its ability to be warped by matter and energy.

Time dilation provides the basis for the twin paradox [3], a hypothetical scenario in which a twin astronaut is travelling in space at relativistic [4] speeds, which is at least a tenth of the speed of light. According to this theory, the astronaut would experience a smaller lapse in time and return to Earth having aged less than his or her twin who remained behind h.

However, NASA's Twins Study [5], which explored the impacts of spaceflight on the human body, published seemingly opposing results. The experiment investigated the differences in twin astronauts Mark and Scott Kelly after Scott Kelly spent a year in flight aboard the International Space Station while Mark Kelly, the control subject, stayed on Earth.

The study discovered that the telomeres in Scott Kelly's white blood cells lengthened while he was in space, but shrunk rapidly and became slightly shorter than their original size after he returned to Earth. Telomeres [6], which cap the ends of DNA strands in order to protect chromosomes, are an indicator of a person's biological age. While they naturally shorten over time, stressors such as smoking, obesity, and other poor lifestyle habits may lead to additional shrinkage. Though the size of Scott Kelly's telomeres eventually stabilized, their decreased length suggested that contrary to expectations, he actually aged more than his twin due to space travel.

Researchers also observed changes in Scott Kelly's gene expression as well as damage to his DNA due to chromosomal inversions. However, more than 90 percent [7] of his genes gradually resumed to their normal state after he returned to Earth. The remaining 10 percent [8] consisted of over 800 genes, of which some were related to immune response and DNA repair. This genomic instability was speculated to increase Scott Kelly's risk of developing cancer, a disease that is correlated with aging.

While the results of the Twins Study seem to dismiss the idea that space travel provides access to a fountain of youth, its results do not undermine Einstein's time dilation theory, as Scott Kelly was far from traveling at relativistic speeds. Moreover, the results of the experiment cannot be generalized and viewed as applicable to all astronauts or individuals, as it had an extremely small sample size of one subject.

In broadening the scope of research, scientists have conducted studies [9] on larger groups of astronauts, as well as on mice [10] that have been brought to space. Experiments on both species have demonstrated that the harsh environment that space travel exposed them to resulted in physical changes resembling aging, such as bone density loss, immune system dysfunction, cardiovascular problems, and the loss of skeletal muscle mass. Many scientists now also leverage space travel to deliberately accelerate aging, allowing them to further study how age impacts illness progression as well as the process of aging itself. Continued research in this area may one day help uncover the secrets of preserving youth for individuals on Earth.

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The Human Brain in a Computer

Written by Kevin Wang
Illustrated by Elizabeth Torna

In 1958, mathematician John von Neumann made a controversial prediction [1]: because of the major differences between computers and the human brain, it would be nearly impossible for technology to ever simulate the brain. 55 years later, in 2009, neuroscientist Henry Markam stood up on a TED stage and made a claim directly contradicting Neumann's [2]. Given ten years, with enough funding and resources, he predicted that he would be able to create an exact computer model of the human brain, down to each individual neuron. By extension, his creation would be as intelligent as humans themselves.

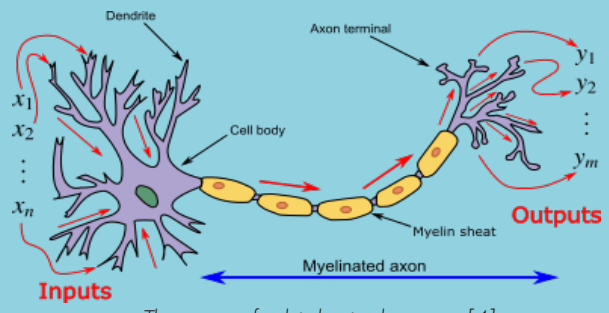
Both of these scientists were game changers in the field of artificial intelligence, or AI. Generally, computers are programmed to perform tasks far more quickly and accurately than the human brain. However, computers tend to struggle with adapting to new situations and finding novel insights that they haven't been explicitly told about. Thus, the field of AI began with the belief that by modeling the human brain, computers could develop intelligence comparable to that of humans. Many techniques have been adopted and discarded over the years, but this general premise has remained the same. The most prominent technique that has arisen is the artificial neural network, or ANN, which is an attempt to mimic the neural network of the brain.

In John Neumann's time, neuroscientists hadn't yet discovered the parts of the brain or the inner workings of memory; however, they understood the basic structure of the neural network [3]. Each neuron receives signals from other neurons at branched extensions called dendrites. Once enough of these signals build up, the neuron sends its own signal out through its axon terminal. The brain is made up of a massive web of connected neurons, which combine to produce our cognition.

ANNs attempt to mimic this structure. Each "neuron" performs calculations: taking in information, deciding how important it is, and producing its own output for the next neuron to receive. The brain and ANNs learn similarly, by strengthening or weakening the connections between biological neurons and, correspondingly, adjusting the mathematical variables in ANNs.

With growing computational power, ANNs have had significant success, gaining the ability to recognize objects and caption images with high accuracy. They model the brain's layer of neurons [4], where the first layer senses every pixel in the image, the second layer senses edges and shapes, and each subsequent layer adds further complexity, eventually recognizing an image. This seems to demonstrate human-like intelligence — the ability to learn from and apply previous experiences.

However, as von Neumann theorized, there are fundamental differences between the two systems. The brain receives a flood of information with a temporal component, as every signal that the dendrite receives lasts for only thousandths of a second. A neuron must receive many inputs in a certain window in order to fire. ANNs, on the other hand, use only one piece of data [5], and perform calculations on that single instance. As a result, computers have difficulty analyzing a constantly changing environment, like that of our world, while our brains operate just fine.



The parts of a biological neuron [4]

This seems counterintuitive. With technological advances, it appears that the computer should far surpass the human brain in processing speed. A computer can perform 10 billion simple operations per second, whereas a neuron can fire at most 1000 times per second. This may suggest that the human brain should be no faster than an ancient computer. However, humans are able to perform split second decisions and make intelligent reactions. This is because the computer performs most operations serially — one operation after another — while the brain works in parallel. A neuron doesn't have to wait for a neuron in another part of the brain to fire; instead, the entirety of the brain operates at once [6].

Ultimately, Markam's attempt to simulate the human brain failed. He found that even modeling the 302 neurons in a roundworm was difficult, not to speak of the 86 billion neurons in the human brain. There are limitations on the extent to which we can model a fundamentally different system. However, these ventures have not been in vain, for the basic structure of the brain has given us inspiration for successful computer algorithms. In the future, as we learn more about the workings of the brain and continue to develop innovative technologies, we may succeed in developing true artificial intelligence.

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HEAT WAVES BEEN FREAKING ME OUT

Written by Laya Divyasree Gollamudi

Illustrated by Tiffany Qian

Unfortunately, heat waves are more than the catchy song by Glass Animals. Alarming headlines such as "New Record-Breaking Temperatures Across the US" may not surprise us anymore because of how frequently they occur nowadays. However, such abnormally high temperatures are powerful indicators of climate change's worsening effects on our everyday lives. For example, the number of people who have experienced heat waves increased by 125 million between 2000 and 2016; in 2021, we saw record-breaking heat waves ravage the western United States, where hundreds in Vancouver, Portland, and Seattle died during the three-day heat wave [1, 2]. As we progress into a world that is increasingly shaped by climate change, it's critical that governments around the world proactively address the issue of extreme heat, especially in cities where people are at greater risk of health problems.

Because over half the global population lives in urbanized areas, and this number is expected to increase, heat waves pose a significant threat to the majority of the population [3]. Any urban region is more susceptible to drastic heat waves due to their heat-absorbing pavements (often made of asphalt) as well as their buildings, which help to concentrate heat in the area. In fact, the risk of death from heat waves is much higher in cities; one study found that extreme heat exposure has doubled in over 13,000 cities from 1983 to 2016, and two cities in the Middle East have surpassed temperatures considered survivable for humans [2, 4]. Exposure to such abnormally high temperatures can have dangerous effects on human health. Severe dehydration causes blood to thicken, making it harder for the heart to pump blood to organs throughout the body. Additionally, heat exposure can impede sweating, the body's natural and most effective way of cooling itself down. If an individual has any preexisting conditions, such as heart disease, these health effects can be exacerbated and potentially lead to death [4].

A study was recently performed to investigate how much of the observed increase in heat exposure in cities is a result of population growth versus how much is a result of physical warming, such as climate change. The study found that overall, heat exposure in urban areas has increased by almost 200%, affecting around a quarter of the global population. Physical warming was responsible for a third of the increase in heat exposure, while the rising urban population was responsible for two-thirds. Furthermore, the authors of the study found that in places with demographic shifts towards cities, the rising population contributed most to the increase in exposure, while in areas with less urban growth, physical warming contributed more. Finally, it was found that in cities with more humidity, physical warming was also the biggest contributor [4].

The results of this study confirm the need for effective policy and urban planning in order to prevent extreme heat's dangerous effects. However, policy in this sector can be complicated due to the disparities in privilege. For example, additional focus must be placed on regions where people don't have access to air conditioning or where people are working outdoors for the majority of the day [4]. One successful example is Ahmedabad in western India, which has taken significant steps to manage heat waves. Their plan involves raising public awareness of protective measures against extreme heat, developing an effective warning system to help predict heat waves, as well as improving training for medical professionals so that they are better equipped to help those that might face harmful health effects from abnormally high temperatures [2].

As heat waves become an increasing threat to a large portion of the global population, cities around the world, like Ahmedabad, must implement effective policy and procedures to prevent the tragedies associated with extreme heat. Planning ahead is crucial because once a heat wave sets in, hospitals become overcrowded quickly and electrical grids crash from the increased use of air conditioning [2]. It is crucial that we develop efficient infrastructure and strategy now because as climate change's effects continue to intensify in the coming years, it will not only help remediate the consequences of heat waves, but will also establish the proper foundations for us to battle climate change in the long run.

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The Iron Man of Neurology

Written by Julia Ann Goralsky
Illustrated by Ananya Raghavan

It involves electrodes, intense surgery, and a battery pack placed inside the body—and no, it will not turn you into Iron Man. It's called deep brain stimulation, and as an already established technique for treating Parkinson's disease, neurosurgeons are now considering its application in psychiatry for common mental disorders including depression, OCD, addiction, Alzheimer's, and Tourette's syndrome [1]. While this might seem like a jolt to your system (see what I did there?), let's pause and first break down the area of the body it concerns: the brain.

The brain is perhaps the most complex and important area of the body, yet one of the least understood. So, for our purposes today, we'll just stick to the basics. The brain consists of cells called neurons, and these cells are responsible for sending messages via electrical and chemical signals. With 100 billion neurons communicating along intricate and diverse pathways, there are multiple ways for these signaling processes to backfire and manifest into physical and emotional disorders. For example, the reduction in dopamine neurons elicit the jerking movements or tremors consistent with Parkinson's disease [2]. In terms of mental illnesses, excess amounts of specific neurotransmitters or chemical signals can lead to the persistent fear or worry characteristic of anxiety disorders [3]. Depression, on the other hand, can be caused by an abnormally small hippocampus, a region of the brain known for serotonin receptors [4].

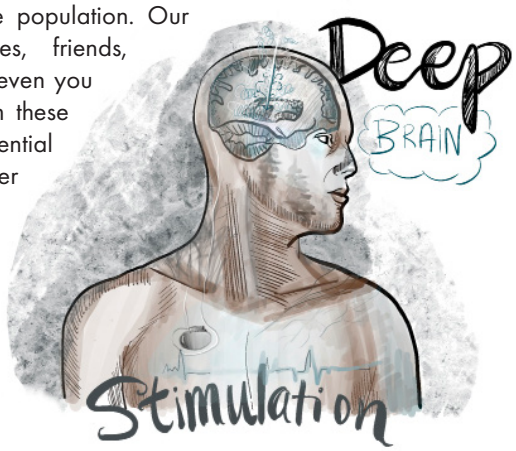
Following the innate complexity of neurons' communication, the solution proposed to resolve symptoms manifesting from 'miscommunication' is correspondingly elaborate. So, back to deep brain stimulation. How does it work? In short, deep brain stimulation involves sending electrical pulses into the brain that are thought to disrupt the erroneous signals sent by neurons. Cool, right? The success of deep brain stimulation is thus a feat of technology. More specifically, neurosurgeons surgically implant electrodes (really thin wires) into a specific area of the patient's brain. An extension wire connected to the electrode is then placed under the skin—passing through the head, neck, shoulders, and into the chest. Here, an internal pulse generator is located, serving as the power source for this treatment [5].

Now, you may be thinking that sticking wires into people's heads and shocking them doesn't seem to be a very smart idea. Is this procedure safe? Well, the procedure involves only minimal risk of permanent damage (more than many neurological procedures can say) and instead boasts a form of customizable care for patients [5]. Yet, this technique of treatment must be specifically selected after careful examination of a patient, often by a team of neurologists, neurosurgeons, neuropsychologists, and psychiatrists.

Already, this technique is fast adapting to use with mental disorders. A study published in Nature Medicine this year detailed a success story for a patient with Major Depressive Disorder. In this case, scientists proposed a "closed-loop therapy" (in contrast to the "open-loop therapy" used with Parkinson's disease and epilepsy) in which they could designate a specific biomarker to monitor an individual's symptoms and thus determine the necessity of administering an electric shock. Through her scores on HAMD-6/VAs and MADRS tests, the study found that the intensity of the patient's symptoms, as well as her overall depression, declined [6].

On a similar note, at Rockefeller Institute of Technology, physicians are trialing the use of deep brain stimulation for opioid addictions, believing that the electrical signals could affect the nucleus accumbens, a reward center in the brain, and thus manipulate the release of dopamine. The preliminary results were positive, with 2 out of 3 patients feeling significant differences that enabled them to maintain sobriety for up to 2 years. Still, while these results are encouraging, more extensive and versatile testing is needed to examine the treatment's application to a wider population. By extension, researchers are also hoping to examine the specific location of the electrode in the brain in order to maximize its positive effects [7].

So why does this matter to you, to me, or to anybody else for that matter? For one, about 264 million people suffer from depression globally [8]. In the United States, depressive and anxiety disorders are among the most prevalent in the population. Our coworkers, classmates, friends, families, and maybe even you personally suffer from these illnesses. Thus, it is essential that we embrace further research with enthusiasm and inspiration for a brighter future—one maybe not with superheroes but instead superpowered technology.



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How Sci-Fi Can Drive Scientific Progress

Written by Charles Bonkowsky

Illustrated by Rebecca Siegel

When a piece of science fiction is released, it's often judged on its relationship to science: how accurate it is, how scientifically plausible the advances in technology or society it proposes are. Advances in science are said to drive science fiction, and older sci-fi is dated by what it imagined the future could look like with a less complete understanding of the universe. Yet the opposite connection is usually overlooked: science fiction can cause advances in science itself.

Science fiction and science research work in a sort of feedback loop: sometimes, science fiction inspires researchers and engineers to push the bounds of theory and technology. Many of the first rocket scientists like Robert Goddard, Hermann Oberth, and Werhner von Braun, were inspired by fictional literature and films such as [2] War of the Worlds (1898) or Frau im Mond (Woman in the Moon, 1929), geostationary satellites[1] were first proposed in 1945 by the famous Arthur C. Clarke [3], and the mobile phone was inspired by [4] Dick Tracy's wrist radio, to name just a few examples. This, in turn, inspires new fiction exploring the implications, and possible consequences, of this progress. Science fiction writers and directors—if they are not scientists themselves—often consult with scientists on technical points, like with the AI researcher Marvin Minsky [5] for 2001: A Space Odyssey or theoretical physicist Kip Thorne [6] on Interstellar.

Not all science fiction works like this. Some works are simply too far into the future (Asimov's The Last Question [7], for example, closes with the heat death of the universe ten trillion years into the future[2]). Some play fast and loose with science in order to tell a better story: faster-than-light travel or communication, which is impossible under the theory of relativity, is the most common violation because having characters wait 200 years for communication between stars would result in a rather dull story. Star

1 Mainly used for weather forecasting, television, communications, and defense. The first of these satellites was launched in 1963.

2 The story was written in 1956: now, astronomers estimate the true heat death of the universe would occur only after the last supermassive black holes decay, 10100 years [8] into the future.

"Jules Verne was in a sense the director-general of my life. When I was not more than ten or eleven years old I read his Twenty Thousand Leagues under the Sea and my young imagination was fired, but I found fault with some features of Jules Verne's Nautilus and set about improving on them."
-Simon Lake [1], one of the first submarine engineers.

Wars has hyperspace, Star Trek has the warp drive[3], and Ender's Game has the ansible[4], and those are just some of the most famous stories which choose to ignore that particular restriction. Thus, most sci-fi ends up—well, nothing more than fiction.

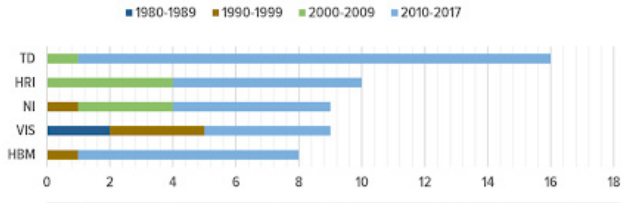
The presence of both these ideas—that science fiction inspires some real-world discoveries, though often anecdotally[5], and that the vast majority of science fiction doesn't result in direct inspiration—raises the question of exactly how large its impact is. Are there just a few scattered researchers who draw their ideas from the literature, or is it a much more prevalent trend than initially imagined?

It's a good question. There aren't a lot of answers.

Philipp Jordan, a professor of computer science at Oregon State University, and his colleagues have done perhaps the most in-depth research [9] of how science fiction is seen and used within the realm of human-computer interaction (HCI). In an analysis of computer science publications over the last few decades, Jordan found that references to science-fiction, general or specific, largely increased over the past few decades:

The number of mentions of 'science-fiction' or related terms in papers published in the proceedings of the CHI conference: the ACM Conference on Human Factors in Computing Systems, considered the most prestigious conference in human-computer interaction. It's where Jordan narrowed his search to.

Even removing false positives where sci-fi was referenced as merely an example of something else (as in an article about digital games, where science fiction is cited as one possible genre), Jordan found that the use of science fiction as a jumping-off point for research or engineering has increased in recent years. The largest number of papers are found in the time period 2010-2017, despite its shorter range.



	HBM	VIS	NI	HRI	TD
1980-1989	0	2	0	0	0
1990-1999	1	3	1	0	0
2000-2009	0	0	3	4	1
2010-2017	7	4	5	6	15

The categories Jordan divides the use of science fiction are, in descending order: Theoretical Design (TD), or 'science fiction prototyping', where designers/writers conceive of new technology and its use in the world; Human-Robot Interaction (HRI), how science fiction portrays humans and AI; New Interactions (NI), how depictions of interactions in sci-fi inspired real-world work; Visions in Computing and HCI (VIS), how sci-fi portrays current technology and society; and Human-Body Modification (HBM), a fairly new field and one which draws heavily on science-fiction inspiration.

This isn't a complete body of research. Science fiction has more applications than computer interactions, and it's used in more than just publication—Jordan Kare [10] of tech company LaserMotive, for example, said that he was inspired to go to MIT and study astrophysics "because the hero of Robert Heinlein's novel Have Spacesuit, Will Travel went to MIT". Now, he's working on laser- and solar-sail technology, first speculated about in 1865 in Jules Verne's From the Earth to the Moon[6].

There are probably thousands of people like Kare, who don't necessarily cite science-fiction in their papers (and thus go unnoticed in research like Jordan's), but are in their present positions and fields because of what they have read. Jordan notes this at the conclusion of his paper, saying "We speculate that the explicit referral of sci-fi in HCI research represents a fraction of the actual inspiration and impact it has had".

But even without exact numbers, it's easy to see that the role of science fiction is vital not only in getting us to where we are today, but in describing what our present looks like and where we go from here. A relatively new concept is that of science fiction prototyping, as mentioned above—unlike conventional science fiction literature, prototyping explicitly tries to create the future it describes. Prototypers take existing research and engineering

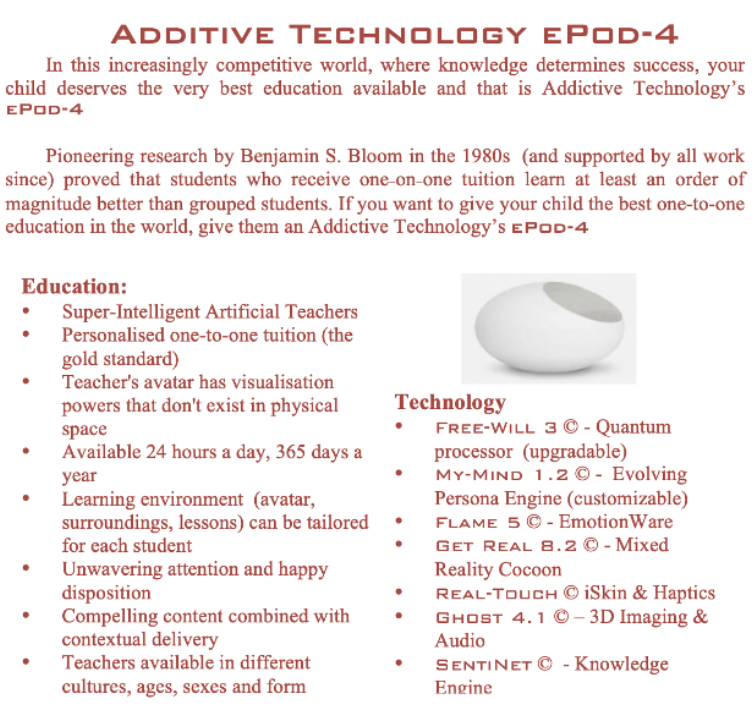
3 To be completely fair to Star Trek, the warp drive is based on a theorized technology called the Alcubierre drive, which circumvents the problems posed by relativity. In essence, a spacecraft would compress the space in front of it and stretch the space behind it, effectively moving faster than light without ever exceeding that speed relative to the space it occupies. There are, however, other physical problems with construction of such a drive.

4 An instantaneous communicator.

5 Martin Cooper, the inventor of the mobile phone, is often cited as being inspired by Star Trek's mobile communicator rather than Dick Tracy's wrist radio.

6 Verne asked [11] "Is it not evident...that there will someday appear velocities far greater than these, of which light or electricity will probably be the mechanical agent?" The first true solar sails in science fiction didn't appear until about a century later [12], in "The Lady Who Sailed the Soul" by Cordwainer Smith.

(especially that of a particular company) and extrapolate its future and possible societal impacts through the lens of science fiction. What gets written about can then be developed into reality. The ImmersaVU, a desk and spherical screen developed by Immersive Technologies Ltd., is one example [13], drawing on Victor Callaghan's Tales From A Pod [14]:



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Top: the ImmersaVU 320. Bottom: a fictional advertisement from Tales From A Pod advertising the educational pod, or ePod. [15]

The prototyping takes advantage of the feedback loop described at the beginning of the article: instead of letting science fiction naturally drive science and vice versa, it takes the reins of that cycle. Brian David Johnson [16], who introduced the idea of prototyping in 2010, has a strikingly similar vision of science fiction to its authors: "science fiction," he writes, "allows us to see ourselves in...the light of a new future; one that is not our own but reflects directly upon who we are and where we might be headed." In much the same way, award-winning author of The Three-Body Problem Ken Liu [17] says that "although science fiction isn't much use for knowing the future, it's underrated as a way of remaining human in the face of ceaseless change." While both knock science fiction's actual predictive record, both speak of its effectiveness in describing the human condition as it relates to technology and our own future.

Whether our ideas of the future can be put to use actively building it, or to provide a glimpse into the lives of the people inhabiting it, is the difference between the two approaches. One is rooted in the concrete world we all live in, while the other has the freedom to explore the worlds we could inhabit as well as the multitude we (for a variety of reasons) can't.

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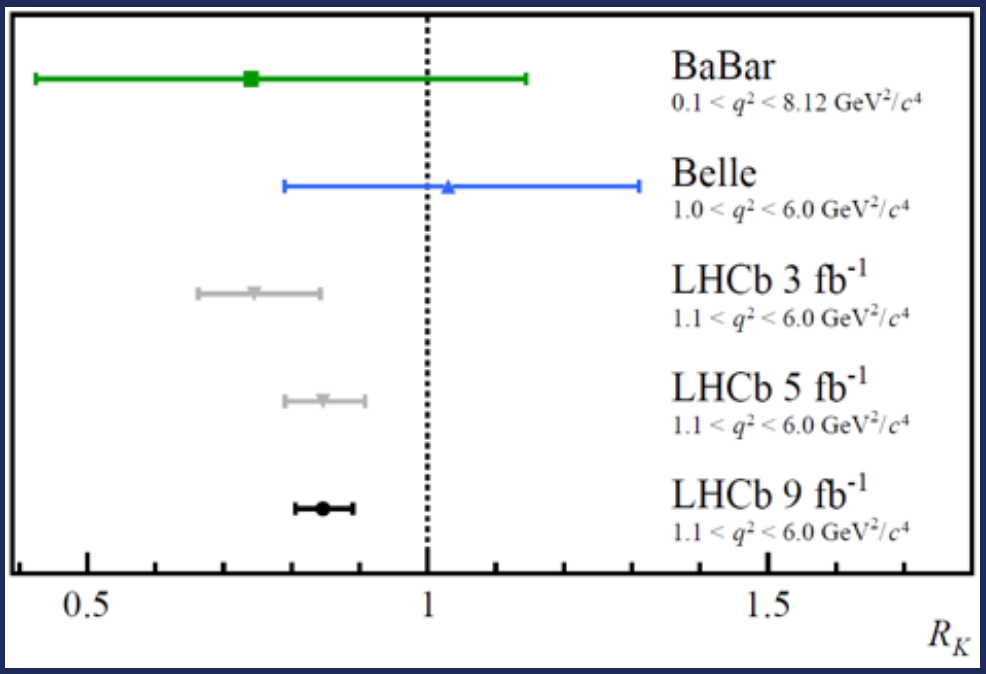
CRACKS in the Standard Model

Written by Charles Bonkowsky
Illustrated by Kate Steiner

For decades, physicists have relied on the Standard Model of particle physics, a theory which describes three of the four fundamental forces in the universe (excepting gravity) to a remarkable degree of precision. It's predicted experimental findings such as the Higgs boson, the top quark, and the tau neutrino far in advance of their discovery, and is the best model of how the universe works to date.

Yet for decades, physicists have also been trying to break the Standard Model. It's not a complete theory by any means: gravity and dark matter, vitally important to understand, are left unexplained. Finding evidence of physics beyond the model would potentially lead to exciting new breakthroughs—but finding those new particles, or strange interactions, has proven to be harder than originally thought. No particle accelerator or experiment has been able to show conclusive evidence yet, though they've produced troves of data.

Now, two different experiments—one run at the Large Hadron Collider (LHC), in Switzerland, and the other at Fermilab, in the US—have published results which may finally show the cracks in the Standard Model.



The black point with error bars indicates the most current measurement by the LHCb experiment. Grey points indicate previous measurements by the LHC. Data from the BaBar experiment, conducted in 2015, and the Belle experiment, conducted in 2019, are also shown. [2]

Lepton Decay

Leptons are elementary particles which are not subject to the strong nuclear force. There are three charged leptons: the electron, the muon, and the tau particle. One principle of the Standard Model is what's known as 'lepton flavor universality' [1]: that the charged leptons act identically, except for small differences due to their mass1. Thus, decays involving leptons should occur with the same probability—or, in other words, the ratio between different decay probabilities should be 1.

The experiment at the LHCb (one of the detectors at the accelerator) tested for this ratio, known as R(k), of how often a bottom quark decayed to an electron-positron pair versus a muon-antimuon pair. What makes this ratio so hard to measure, especially in previous experiments on lepton flavor universality, is that this type of decay is extremely rare: bottom quarks decay into leptons about one time in two million. Thus, the LHC's data had to be collected over five years—but what it did find has excited physicists looking for evidence of new particles.

1 The muon is about 5 times heavier than the electron, and the tau particle about 3 times heavier than the muon.

If three sigma isn't enough for you...

R(k) was measured [2] to be 0.846—that is, for every 100 electron decays, the experiment measured only 85 muon decays, in violation of what the Standard Model predicts the ratio should be. And other data, from previous years and experiments, points in the same direction.

There's reason for caution. Currently, the finding has a significance level of 3.1 sigma. Sigma, in this case, corresponds [3] to a p-value—for three sigma, p is equal to about 0.003. That value means that, if there is no violation of lepton universality, there's about a 0.3% chance that researchers would still observe a discrepancy this extreme or more. In particle physics, 3 sigma is enough to claim evidence for a new finding, but it takes a significance level of 5 sigma2, or a p-value of 0.0000003, to claim a discovery.

So it's evidence, not a discovery. But the evidence is compelling, not just because of the data but because of what it represents. "If a violation of lepton flavor universality were to be confirmed, it would require a new physical process, such as the existence of new fundamental particles or interactions," said [4] spokesperson for the LHCb experiment Professor Chris Parkes. Paula Cartelle, a lead researcher on the study, agrees: "This new result offers tantalizing hints of the presence of a new fundamental particle or force." [5]

Others are more skeptical. "I am hereby offering a US $1000 bet on the following stipulation: Within the next 5 years, no LHC experiment will publish a scientific article claiming that lepton universality has been conclusively disproven," writes experimental physicist Tommaso Dorigo [6]. After all, he won the same $1000 bet back in 2006 for sticking with the Standard Model, and there's been plenty of two- and three-sigma "evidence" which have either never panned out or have been shown to be nothing more than a fluke when experiments are rerun.

Although...if three sigma isn't enough for you, what about four sigma?

The Muon g-2 Anomaly

Muons wobble in a magnetic field, and the results of the long-awaited Muon g-2 experiment from Fermilab published on April 7th, 2021 confirmed [7] that muons wobble ever so slightly more than they should as predicted by the Standard Model. The measured values have a significance of 4.2 sigma, well on the way to the 5-sigma benchmark needed for a discovery (although it's still just evidence, and the same reasons for caution apply here as they do to the LHC data).

2 Basically, if the discovery isn't real, then only one in every 3.4 million experiments should get the same result as the researchers.

The background to the Muon g-2 experiment, which published the results, is long and storied. Since muons are slightly magnetic, they have a property known as a magnetic moment (denoted as g) which affects how they rotate in a magnetic field. The theoretical physicist Paul Dirac, who helped establish quantum theory, derived a formula back in 1928 that predicted [8] the magnetic moments of both a single muon and electron should be exactly 2.

However, in 1947, two physicists showed [9] the magnetic moment of the election was equal to about 2.00232. Minuscule quantum fluctuations cause electrons to emit and then reabsorb a photon, and change its magnetic moment slightly. This can happen with a variety of particles, known as virtual particles given that they pop in and out of existence on incredibly short timescales. The type and rarity of those virtual particles (heavier particles affect the moment more, rarer virtual particles affect it less) determine what the magnetic moment should be. So scientists set out to do two things:
Calculate g to an incredibly precise degree using our knowledge of what particles exist and how they interact with the muon
Measure g to an incredibly precise degree using a magnetized ring and accelerator.

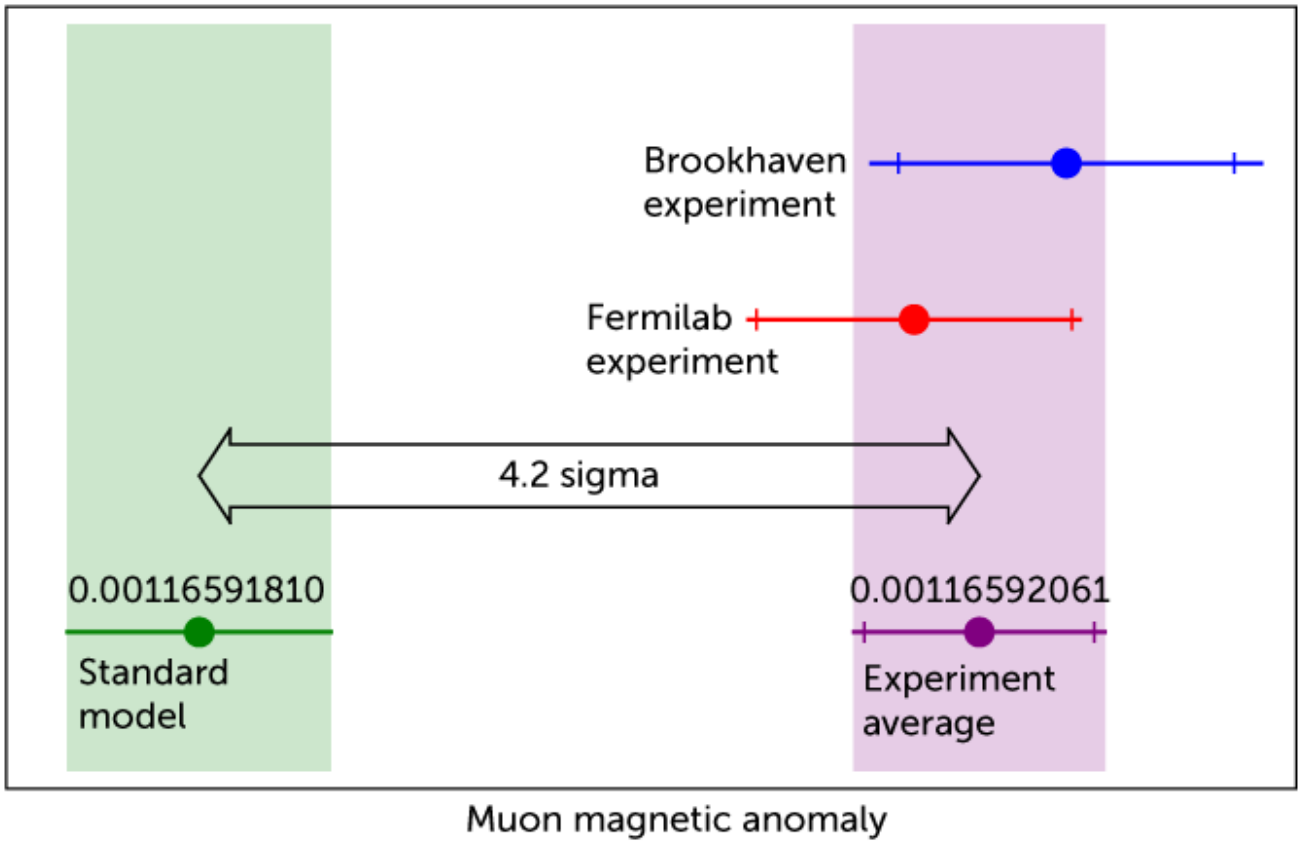
(And precise means precise: the difference between theory and experimentation that marks these findings is only present at the eighth decimal place or so)

In the 1990s, an experiment [10] from the Brookhaven National Laboratory measured g to be ever so slightly different from what the Standard Model predicted it should be, but the finding only had a significance level of about 3 sigma3, and re-running it wouldn't have increased the sigma level. But technology marches on, and in 2013, the magnetic ring used in Brookhaven was shipped to Fermilab, with a goal of acquiring at least twenty times more data than the Brookhaven experiment had.

They will—these preliminary findings represent only 6% of the total data the Fermilab experiment hopes to eventually collect. And during the analysis, the group of scientists working on the data were blinded [8] to its actual results, in order to avoid human bias. The final calculation of g depended on a particular value, the rate of the master clock which measured the muon's wobble, which was written down and locked in offices at Fermilab and the University of Washington. Only at the end of February, when the analysis was complete, was the number revealed and entered into the analysis programs which allowed them to see their results.

3 Accuracy of the results and more data being added means that the significance varied between 2.7 sigma and 3.7 sigma, where it sits today.

...what abo



Results of the Brookhaven and Fermilab experiment as compared to the Standard Model prediction. [7]

All the usual caveats for caution apply: results which promise to overturn the longest-standing model in particle physics have not so far managed to do that, and there is one additional wrinkle. Published the same day were the results of the BMW collaboration, [11] which set out to calculate the Standard Model's prediction of g once again by incorporating all possible ways a muon could interact with the universe around it—a process which took thousands of individual sub-calculations and triple-digit hours of supercomputer time. Their calculation of g was exactly in line with the Brookhaven and Fermilab results, meaning that they, potentially, don't differ from the Standard Model at all.

(Although even then, the fact that the supercomputer calculation and previous, data-driven calculations like those used by Fermilab differ could also be a sign of new physics that we don't yet understand)

What Comes Next

Data. And more data.

The LHCb is restarting this year after a series of upgrades during 2019-2020, and Fermilab still has 94% of their data left to report (as well as an ongoing fourth run to collect even more). This evidence is cause for excitement, but there's still a lot of work to be done.

out four sigma?

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A Computational Approach to Analyzing
College Facebook Confessions

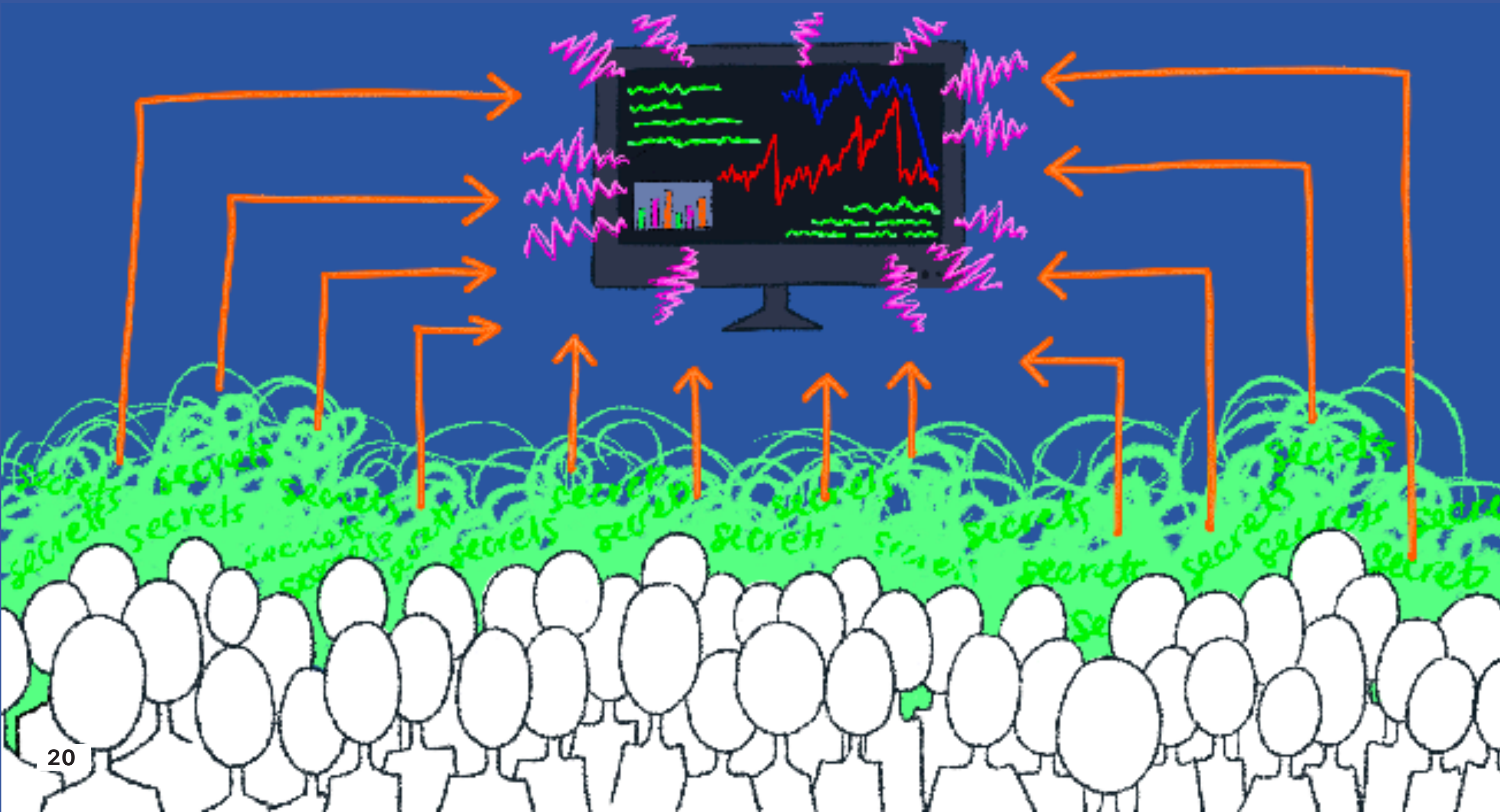
Written by Eleanor Lin
Illustrated by Aeja Rosette

Whether soliciting advice in a newspaper column or posting on social media, people often feel more comfortable discussing sensitive topics under the cloak of anonymity [1]. For college students in particular, Facebook confessions pages are a common means of discussing controversial topics. But is there a way to move from qualitative observations of confessions boards to a more quantitative understanding of what topics students are posting about, how their audiences are responding, and how these topics are influenced by their campus environments and global events?

These are the questions that Soubhik Barari, a computational social science researcher, set out to answer in his 2018 article "Analyzing Latent Topics in Student Confessions Communities on Facebook" [2, 3]. Drawing together a dataset of 170,000 confessions posts from American universities' Facebook confessions pages, statistics on those universities' campus environments, and current events from Twitter, Barari reaches some interesting conclusions on this distinctive social media ecosystem.

First, in order to determine which topics occurred in the dataset and to label the main topic of each post, Barari used an approach called human-in-the-loop topic modeling. Using a probabilistic method called latent Dirichlet allocation, combined with manual selection, he grouped together frequently co-occurring keywords from posts into sets that represent different topics [4]. Each post was then labeled as belonging to the single topic for which it contained the most words in the associated set. Posts were also labeled according to whether they referred to global or campus events. Finally, each post was analyzed to count how many words reflecting a given cognitive state (e.g., "anger" or "anxiety") were contained in it.

Some results, such as the higher proportion of anxiety-related words in the pages of top-ranked universities, may not surprise readers familiar with Ivy League stress culture [5]. Other findings are more striking. For instance, pages that mentioned romantic and sexual topics more frequently mentioned mental and physical health less frequently, and vice versa. Posts at colleges with a higher average tuition had higher odds of mentioning race and ethnicity, but not of mentioning socioeconomics. Furthermore, less racially or ethnically diverse colleges did not have significantly fewer posts related to race and ethnicity. However, based only on the proportions of different topics occurring in a college's confessions board, a machine learning algorithm was able to predict with 84% accuracy whether a school was very white (defined as having a student body consisting of



over 80.9% white students) or more diverse (less than 45.3% white students). Finally, political posts received significantly less engagement, as measured by comments and likes, than posts on other topics.

While Barari's meta-analysis certainly sheds light on the character of Facebook confessions boards at different kinds of universities, it's important to also consider his study's limitations. As he acknowledges, since posts were only labeled with one topic, no information about possibly co-occurring topics within individual posts could be inferred. Furthermore, readers should keep in mind that Facebook activity may not be perfectly representative of a student body's social or social media behavior more generally, and that the content of a confessions page is partly determined by its admins, who may exercise their power to post or not post submitted confessions to varying degrees.

> "Posts at colleges with a higher average tuition had higher odds of mentioning race and ethnicity, but not of mentioning socioeconomics."
>
> Like Comment

Nevertheless, Barari's analysis offers plenty of food for thought on the complex social dynamics at play within and beyond American college campuses. No matter the time or place, factors such as race and ethnicity, socioeconomics, and the current political climate are bound to interact and influence contemporary discourse in surprising ways, in the online as in the physical world.

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COVID-19 BABIES

Written by Angel Rose Latt
Illustrated by Aeja Rosette

The tiniest of humans are apparently turning out to be the strongest in the era of COVID-19. Thirty-six weeks into her pregnancy, a Floridian frontline health-care worker received her first dose of the Moderna COVID-19 vaccine. Three weeks later, she gave birth to a healthy baby girl, delivering a surprise that shocked even the doctors in the delivery room: COVID-19 antibodies. Remarkably, this is the first known case of a baby born with coronavirus antibodies in the United States [1]. Along those lines, further emerging research has uncovered that other pregnant women who have been vaccinated against COVID-19 will pass along such antibodies to their babies, dispelling worries over the potential risk and harm associated with vaccinating pregnant people.

Perhaps unsurprisingly, pregnant people are more likely to contract severe illness from COVID-19 compared to their non-pregnant counterparts [2]. More specifically, a COVID-infected pregnant individual is 1.3 to 1.4 times more likely to face hospitalization [3], and the fatality rate from COVID-19 is 13.6 times greater [4] than that of nonpregnant individuals of the same age. In addition to the devastating effects of contracting COVID-19 that include intensive care admission, respiratory complications, ventilation, or potential death, pregnant people are at risk of adverse pregnancy outcomes such as premature birth. Additionally, pregnant individuals who are Black or Hispanic [5] are disproportionately affected by COVID-19, increasing complications in these populations drastically.

"In spite of the lack of guidance, most pregnant mothers say they would be in favor of receiving the COVID-19 vaccine."

Despite these higher risks of COVID-19 complications, there exists rather limited research regarding the safety of COVID-19 vaccines on pregnant people, for nearly all COVID-19 vaccine trials have excluded pregnant and lactating participants [4]. While vaccine studies on pregnant individuals are lacking, vaccine studies in animals receiving the Moderna, Pfizer, and Johnson & Johnson's Jansen vaccine before or during pregnancy did not discover any significant safety concerns [2]. When testing the mRNA vaccines and the J&J vaccine in animal

studies, the vaccines were proven to show no effect on fertility or interfere with pregnancy [6]. As of now, researchers believe that the Moderna and Pfizer mRNA vaccines and the J&J/Jansen viral vector vaccines do not pose any major threats to pregnant people because of the biochemical mechanisms that they utilize, but much of this research is still underway.

In spite of the lack of guidance, most pregnant mothers say they would be in favor of receiving the COVID-19 vaccine. Vaccine acceptance was highest in India, Philippines, and South America, and the lowest in Russia, the U.S., and Australia [7], which can be a result of COVID-19 denial in Russia and the U.S., as well as the decline of COVID-19 in Australia. Surveys have found that vaccination hesitancy in pregnant people stems from concerns regarding how the vaccine will affect the fetus. Fortunately, current vaccines do not use live viruses, so it is unlikely to pose a threat to the developing fetus. For further assistance and advice, pregnant individuals may communicate with their healthcare provider.

Despite the limited data about the vaccine on pregnant individuals, there is new evidence that suggests immunization in mothers can protect newborns from COVID-19. In February of 2021, doctors reported for the first time the presence of SARS-CoV-2 IgG antibodies in the cord blood of a Floridian frontline health-care worker who received the Moderna vaccine [8]. The presence of antibodies in the cord blood indicates the transfer of maternal antibodies across the placenta to the fetus. Echoing these discoveries, another earlier study revealed that out of 83 pregnant women who tested positive for COVID-19, 72 had SARS-CoV-2 IgG antibodies transferred across the placenta [9]. Though, this finding does come with a slight caveat; the team of researchers found that in order for maternal antibodies to present themselves in the cord blood after infection, they must develop a minimum of 17 days before birth.

While recent revelations on maternal and neonatal antibody transfer seem promising, more research is needed to demonstrate the efficacy and safety of COVID-19 vaccines on pregnant people. However, at the end of the day, science suggests that receiving the COVID-19 vaccine should lend way to favorable outcomes for pregnant people.

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