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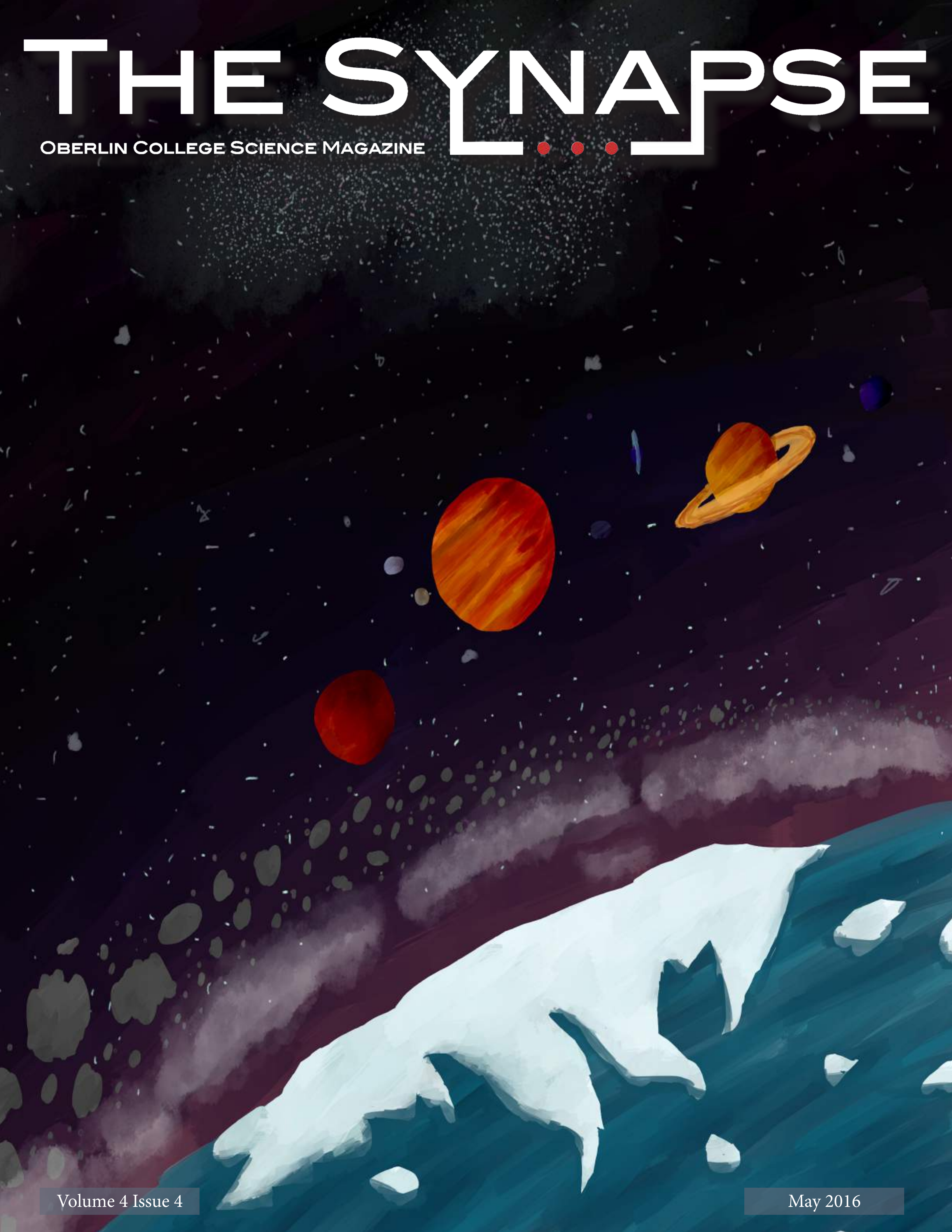

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Staff

The Synapse would like to thank former Managing Editor, Nate Bohm-Levine, and Art Coordinator, Peyton Boughton, for their dedicated work over the past year. You will be missed!

Interested in joining our team?
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It has been a summer for science. The only parallel I can draw between the pace of scientific advancement over the past 365 days is with the sparseness of its appearance in mainstream media. Unfortunately, science has not yet made its way into the discussions of our presidential nominees and, as such, many researchers have gone without the reecognition they deserve. However, this lapse on the part of the media leaves ample space for publications, such as *The Synapse*, to offer their take on these important developments.

In the 1960s the United States captivated the world with footage of Neil Armstrong skipping across the moon's surface. This monumental event, which marked the end of a decade-long race, emboldened another just as swiftly. Mankind's foray into outer space sparked an intellectual race that quickly outstripped the space race. Today the Apollo 11 mission stands as a milestone in our collective history and source of continued inspiration for young minds.

This past year, mankind has often stood on the brink of discovery and the unknown, striving to overcome the latter for the merits of the former. In China, a radio satellite with 70,000 m^2 of collecting area is nearing completion. In the USA, pharmaceutical companies and the Obama administration have pooled their resources in an effort to cure cancer. In the United Kingdom, scientists were given the go-ahead to modify human embryos using the gene-editing technique CRISPR/Cas9. With such innovation on the rise, we truly live in an age of splendor.

While science journalists cannot (and probably never will) trump the appeal of national politics, we can offer a source of respite from an otherwise tumultuous world. Within the pages of this magazine, we humbly offer a view of the natural world as we see it: complex, breathtakingly beautiful, accelerating swiftly, and filled with opportunities for young scientists to proffer their talents to the world.

For every issue of this magazine, we ask our artists to chose one article to work from that inspires their creativity. No better example of the fruits of this collaboration can be found than in *A Brief History of the Universe*. For this issue, I asked five of our artists to create a work of art inspired by a description of a moment in our cosmic calendar, a task that they executed with exceptional skill.

Enjoy.

Gabriel Hitchcock
Editor-in-Chief

A Brief History of the Universe

13.8 billion Ago

"One trillionth of the size of the point of a pin . . . this was the entirity of the universe."

Zoe Cohen

377,000 years later

"This new dawn was ushered in by a new particle: the photon."

Zimeng Xiang

150 million years later

"The radiation streams outward in a condensed jet of incredible luminosity."

Rachel Dan

13.21 billion years ago

"The spiraling arms funnel gas into the center of the young galaxy . . . operating as a galactic nursery."

Beatrix Parola

4.4 billion years ago

"Once sufficiently dense a protostar ignited at the center. It was thus that our sun was born."

Mikaila Hoffman

4.4 billion years ago

"The early Earth was a hellscape of molten earth, solar radiation, and frequent asteroid collisions."

Rachel Dan

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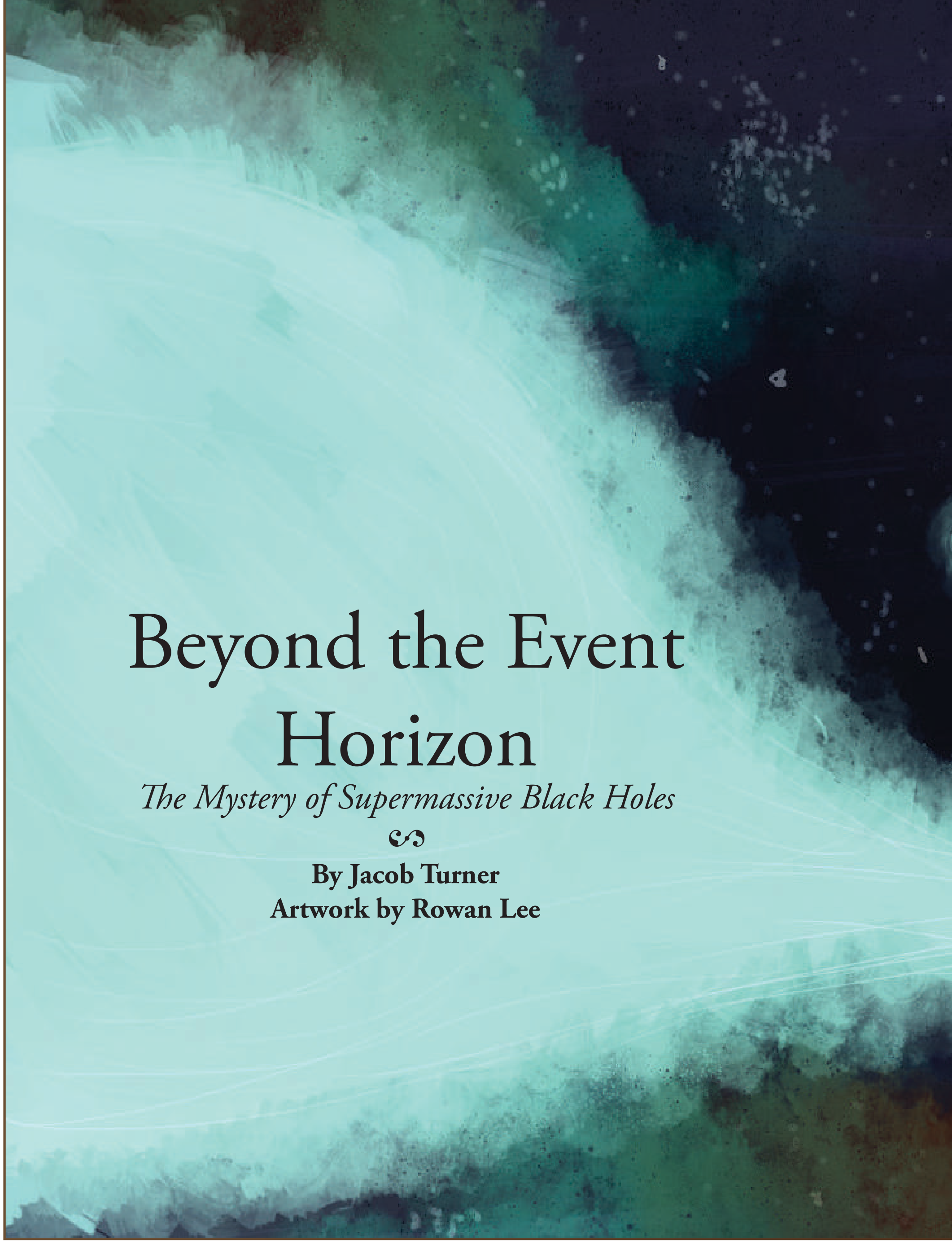


Beyond the Event Horizon

The Mystery of Supermassive Black Holes

By Jacob Turner
Artwork by Rowan Lee

Once again, black holes have found a way to make us question how well we understand the evolution of the early universe. A group of astronomers has recently discovered a galaxy featuring a host black hole that seems to have no right being there. This galaxy—around 200 million light years away—is in a part of our local universe that is relatively sparse, consisting of only ten or twenty other galaxies. We typically expect to find galaxies with more massive black holes within densely packed groups of hundreds to thousands of galaxies. Yet this galaxy, more or less in the cosmic suburbs, has one of the largest black holes ever discovered, with a mass of around 17 billion times that of our sun. By comparison, our galaxy's host black hole is only about 4 million times the mass of our sun. Considering what we think we know about how galaxies and black holes form and gain mass, how can we reconcile this contradictory discovery?

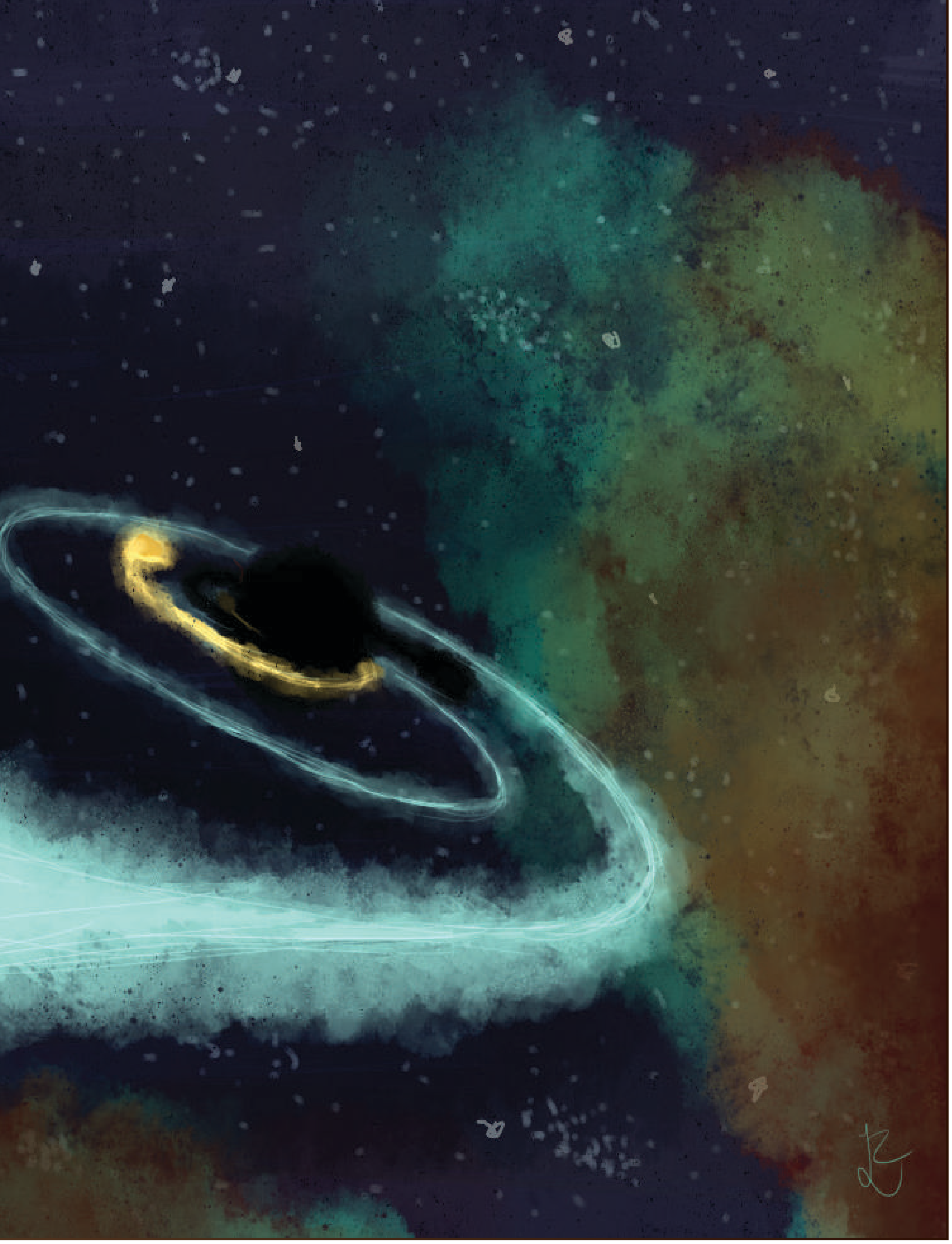
Before exploring this issue further, it's important to understand the strange characteristics of black holes. These objects are among the most extreme physical systems that exist in our universe. So they are perfect, not only for testing the limits of our current models, but also for creating new frontiers, as was recently done with the detection of gravitational waves in September 2015.

Let's consider a star around 3 times the mass of our sun, which is thought to be the minimum mass requirement for forming stellar mass black holes, i.e. a black hole formed from a star. Such a star, like all other stars, experiences a constant battle between two forces fighting for dominance beneath its surface. On one hand, you have the outward pressure created by the release of energy from hydrogen atoms fusing into helium atoms within its core. On the other hand, you have the gravitational curvature from the massive star's warping of local spacetime, which is causing the star's matter to fall back in on itself.

Eventually, the star runs out of hydrogen fuel and has to resort to fusing heavier elements in a futile attempt to maintain stability. Once it gets to iron, the reaction begins absorbing energy rather than releasing it, and so gravity wins, causing the star to implode in a fraction of a second before the massive pressure buildup at the core from the infalling material causes a massive outward explosion of gas. The star has now gone supernova, and it will likely outshine all of the other stars in its host galaxy for a few years. What remains within the gas from the supernova is a distortion of spacetime a few kilometers wide known as a black hole, a compact spherical void where the star used to be.

It can be very difficult to picture what a black hole looks like, and we are usually only able to infer the presence of one if an accretion disk has formed around it or if we observe a star orbiting around an apparently empty patch of space. We can now also infer their presence if they emit gravitational waves, although this technique is currently limited to very massive black holes in binary systems. If you wish to see a relatively accurate depiction of a black hole, I would highly recommend seeing the movie Interstellar, as the black hole in the film is rendered primarily through the extrapolations of general relativity.

Since a black hole's escape velocity—the velocity needed to escape the gravitational influence of an object—exceeds that of the speed of light, any matter travelling within a certain distance of the black hole is now powerless to resist the black hole's gravity and falls inwards. Since light is the fastest thing in the universe, we can only receive information at speeds up to the speed of light. Therefore, any events that occur within a certain region near the black hole can never be observed. This perimeter around the black hole is known as its event horizon. The physics needed to describe what happens beyond the event horizon are undiscovered, and will require the unification of general relativity with quantum mechanics into a theory of quantum gravity in order to be properly understood. However, while our applications of quantum mechanics to black holes have been few and far between, Stephen



Hawking has shown that black holes will eventually evaporate by emitting high energy particles from the event horizon via a process now known as Hawking radiation.

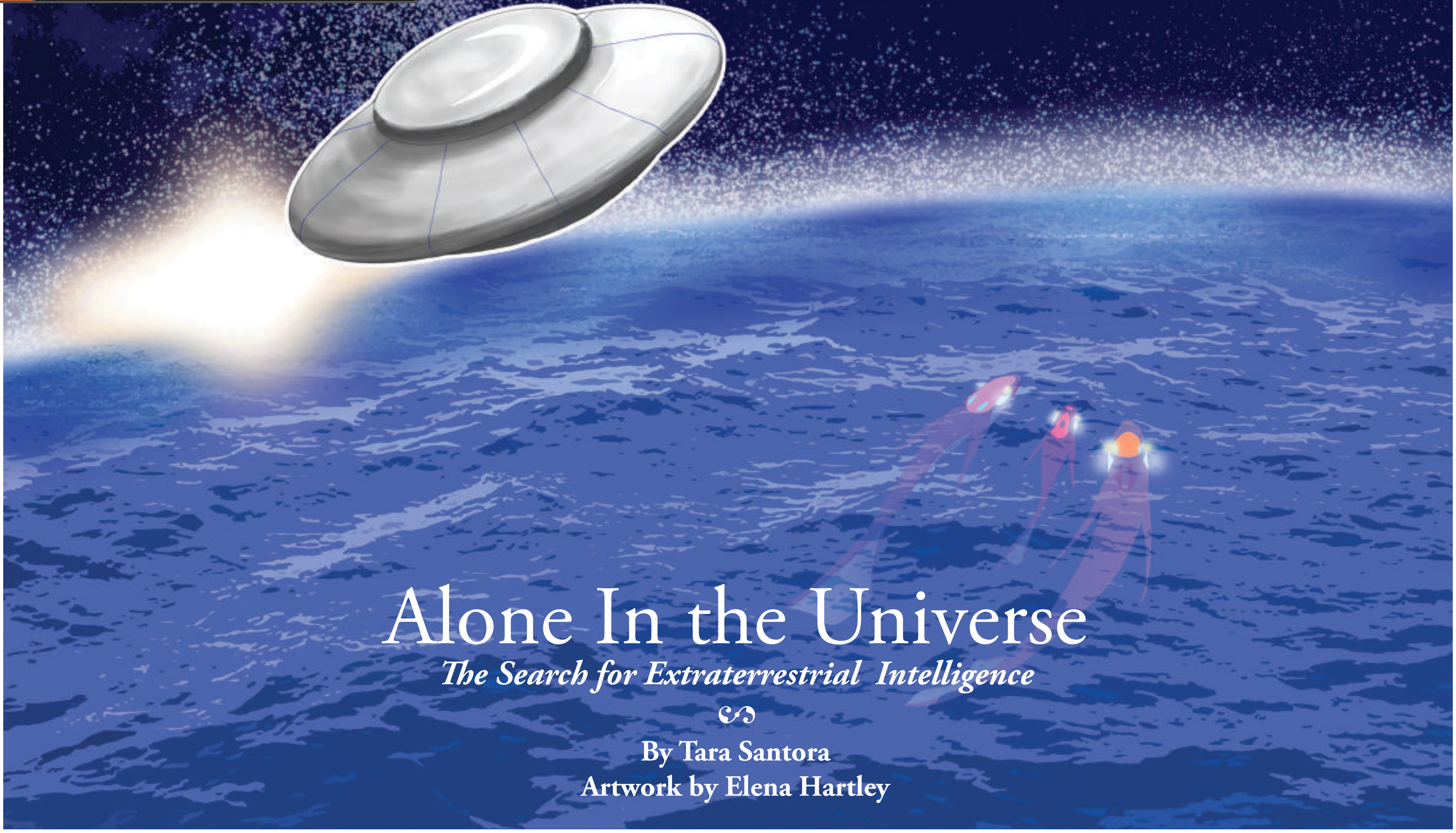
Hypothetically speaking, any object is capable of becoming a black hole, provided its mass is compressed into a small enough region of space. Crushing the Earth down to the size of a grain of salt or a human down to 100 billion times smaller than a proton would produce a black hole, albeit very small ones that would evaporate almost instantly. A big reason why we only hear about black holes resulting from objects the mass of stars or larger is that they have an accessible mechanism from which to form and can last hundreds of trillions of years before evaporating.

The black holes that are at the heart of this new discovery are what are known as supermassive black holes, which reside at the centers of almost every galaxy. These objects can range from hundreds of thousands to billions of times more massive than the sun. It is currently unclear as to how supermassive black holes form, although it is thought that they are the remains of the first generation of stars, which may have been hundreds of solar masses. After forming, they grow larger by feeding off of nearby matter and by merging with other black holes. One characteristic of which we are almost certain is that supermassive black holes must have formed in the very early universe, either within or before the first galaxies, less than one billion years after the Big Bang. Since back then the universe was much smaller, everything in it was a lot closer together, which provided a steady stream of fuel for primordial black holes and allowed them to achieve such high masses.

When these black holes first formed, they had such a large influx of matter flowing onto their accretion disks that massive amounts of friction were generated, resulting in powerful jets of radiation being emitted from opposite sides of the black hole. These jets made their host galaxies some of the brightest objects in the universe, and they remained so for hundreds of millions of years, eventually running low on nearby sources of fuel and becoming the more dormant supermassive black holes that exist today.

What's puzzling about the recent discovery is that a 17 billion solar mass black hole was found within a rather small galaxy cluster with little to offer in the way of a stellar fuel source. We would expect to find dormant black holes in relatively dense clusters with an abundance of stars, so it was a surprise to find such a large black hole in a galaxy that was so diffuse at its center. A possible explanation is that this black hole is a binary formed after the merger of two galaxies earlier in the universe, when collisions were more frequent and stars were more abundant. Another possibility, maybe even connected with the previous one, is that the region around the black hole is so barren is simply because the black hole was so active early on in its life that it has already used up its fuel sources or flung them out of the galaxy altogether. What's more, this galaxy is by far the brightest among its neighbors, something which is quite rare in small clusters and giving some credibility to the idea that this galaxy may be the result of multiple mergers.

Questions raised from discoveries such as this one indicate that there is still much to be learned about the structure, formation, and evolution of our universe. Objects such as black holes appear to play key roles throughout, and it may be that unlocking their secrets will give us an unparalleled insight into the inner workings of the cosmos on the grandest of scales.



Alone In the Universe

The Search for Extraterrestrial Intelligence

By Tara Santora
Artwork by Elena Hartley

Look, there in the sky! It's a bird — it's a plane — it's a...UFO? Probably not. UFOs, or Unidentified Flying Objects, have been the objects of conspiracies since the first well-publicized sighting in 1947 (although some conspiracists claim that the sightings go as far back as 214 BCE). In the 1947 sighting, a pilot named Kenneth Arnold was flying a small plane near Washington's Mount Rainier. Arnold claimed that, during his flight, he witnessed nine crescent-shaped UFOs glowing blue and white, flying in a "V" formation, skipping through the air at thousands of miles per hour.

After this event, UFO sightings became increasingly reported, and the U.S. government decided to take action. In 1948, the U.S. Air Force began investigations into the sightings, and within four years these investigations turned into Project Blue Book, centered in Dayton, Ohio. From 1952 to 1969, Project Blue Book analyzed over 12,000 claimed UFO sightings. A team of physicists, the Robertson panel, met in 1953 to analyze the sightings recorded thus far. The scientists determined that 90% of the sightings could be conclusively dismissed as either natural phenomena such as bright stars and planets, meteors, auroras, and ion clouds or as human-made objects including aircraft, balloons, and searchlights. The other 10% of sightings did not contain enough information to make conclusions. A second committee released the Condon Report in 1968, which drew similar conclusions to the Robertson panel and led to the discontinuation of Project Blue Book.

Even though most scientists agree that we have not yet made contact with extraterrestrial life (especially not through UFO sightings), a significant amount do believe that intelligent life exists beyond Earth. Since the galaxy is so large, and humans have not even come close to discovering all of its mysteries, some find it difficult to believe that Earth is the only planet with the conditions necessary to host intelligent life. Those who believe this cite the Drake Equation, designed in the 1961 by the astronomer Frank Drake, which is used to calculate the probability of finding extraterrestrial intelligence, also known as ETI.

	The Drake Equation $N=(R^*)(f_p)(n_e)(f_l)(f_i)(f_c)(L)$
N	Number of civilizations in the Milky Way whose electromagnetic emissions we would be able to detect
R^*	Rate of formation of starts suitable for the development for intelligent life
f_p	Fraction of these stars with planetary systems
n_e	Number of planets per solar system with an environment suitable for life
f_l	Fraction of suitable planets on which life actually develops
f_i	Fraction of life-bearing planets on which intelligent civilizations develop
f_c	Fraction of intelligent civilizations with technology that emits detectable signs of their existence into space
L	Length of time such civilizations emit detectable signs into space

The original estimates used for the variables in the Drake Equation yielded the prediction that there are 18,750,000 communicating civilizations in the Milky Way. Using information that has been discovered since the original calculation, the current optimistic estimate is 72,800 while the current skeptical estimate is 1 communicating civilization in our galaxy. That 1 civilization would be us Earthlings. Of course, the values of the variables being used in the equation are all estimates and are highly debatable, so one cannot be sure of which prediction is the most accurate. Of the more optimistic scientists, some conclude that, if extraterrestrial intelligence does exist elsewhere in the galaxy, the extraterrestrials are likely to attempt to contact and communicate with other lifeforms such as us. This is one of the core principles that justify the search for extraterrestrial intelligence.

A physicist named Enrico Fermi, who once built a fully-functioning atomic reactor in a squash court, was one of the pioneers of the Search for Extraterrestrial Intelligence (SETI). In the 1940's, Fermi realized that any extraterrestrial society with decent rocket technology would, within a timespan of ten million years, be able to colonize an entire galaxy. This realization includes the Milky Way, our home galaxy. While ten million years may seem like an impossibly long time to us puny humans, the galaxy has been in existence for approximately ten thousand million years. This gives extraterrestrial societies quite a bit of wiggle room to colonize the galaxy.

Obviously, we have not yet been colonized by aliens. But Fermi believed that extraterrestrial intelligence is probable. Why then have we not yet been contacted by otherworldly beings? In Fermi's words, "Where is everybody?"

The Fermi Paradox is the question of why we have not yet had communication with extraterrestrial intelligence if such beings exist. SETI researchers believe it is too simplistic to conclude that ETI does not exist from the fact that we have not had communication with extraterrestrials. Instead, there are many possible solutions to the Fermi Paradox. One possible solution is the Zoo hypothesis, which conjectures that extraterrestrial intelligence could be observing us without our awareness. Another potential explanation is that ETI are trying to communicate with humans, but we aren't listening properly. There are many more potential solutions to the Paradox, none of which can be proven since we have little evidence.

But SETI researchers are not giving up; instead, more scientists are searching for signs of ETI than ever before. Several methods are currently being used to look for these signs. One of the major methods SETI is using to find potential contact is by monitoring for transmissions in electromagnetic radiation (essentially radio signals). This technique began in 1960 with Project Ozma, named for the land of Oz and founded by the same Frank Drake of the Drake Equation. Project Ozma monitored electromagnetic radiation transmissions for a series of prime numbers or for uniformly patterned pulses, potential signs of intelligent communication. However, Drake's team found no evidence of this kind.

To be able to detect a message, the equipment that receives the radio signals must be pointing in the right direction, which makes this type of SETI extremely difficult. Another drawback to monitoring transmissions is that the machines that sense the radio signals must be programmed to the correct range of frequencies. If an ETI transmission was outside of a machine's particular range, the message would go undetected. Of course, ETI that wish to communicate may even choose a different medium of communication from radio signaling. Additionally, ETI may not have yet developed radio technology; after all, we humans have only had it for about 100 years.

One of the most famous SETI radio transmissions ever recorded occurred at the Ohio State University Radio Observatory, also known as the Big Ear. In 1977, the Big Ear's radio telescope picked up on a powerful signal, far too strong to be background noise while pointing towards 3 star systems named Chi Sagittarii. The signal lasted for 72 seconds and is the only signal of its magnitude ever recorded. The strength of the signal was so jarring that Jerry Ehman, the astronomer who had been monitoring the telescope at the time of the transmission, wrote in the margins of the printed transmission, "Wow!". Since then, this peculiar transmission has been known as the Wow! signal. However, as this extraordinary signal was the only transmission ever detected that could potentially be from ETI, most scientists dismiss it as a fluke. In fact, recent studies have hypothesized that the Wow! signal was transmitted by a comet that may have emitted neutral hydrogen (which is the same frequency of the detected signal) while passing through the Chi Sagittarii. Scientists plan to test this potential explanation as the same comet is projected to soon pass through the same location.

Another potential means of communication that has become increasingly monitored in recent years is optical SETI, which monitors lasers. Optic SETI is favorable because, unlike with radio transmissions, the laser detection equipment has no possibility of interference from Earth-bound sources. However, lasers only emit light on one frequency, so researchers searching at the wrong frequency would miss the signal. The ETI might combat this problem by emitting light in narrow pulses of various frequencies, which would increase the probability of detecting one of the emissions. Another problem with optical is that lasers are highly directional, even more so than radio waves, so there is a lesser likelihood that the laser-sensing technology will be pointing in the proper place to detect a signal. Additionally, radio signals could be accidentally emitted by ETI, which increases the chance of researchers finding signals, but optical SETI would only be released deliberately by other lifeforms.

Instead of simply waiting for ETI to contact us, some researchers would prefer to send deliberate signals, called active SETI, in hopes that another intelligent civilization will receive our contact. However, the ethics of this are highly controversial. Opponents of active SETI, including famous physicist Stephen Hawking, fear that alerting other intelligent civilizations of our presence could be dangerous in case the ETI are malicious or imperialistic. Supporters of active SETI argue that the potential benefits of active SETI outweigh the risks. One of these potential benefits is that an intelligent civilization may be younger than ours, and they may have not yet developed the technology that can send messages to other civilizations. If we make the first contact with these civilizations, the Earth messages could help the younger civilizations to produce a response. Additionally, if every intelligent civilization sits back and waits for signals from other lifeforms, never emitting their own messages, then the different civilizations will never become aware of one another.

Before the fierce international debate began, several active SETI projects did exist. The most famous of these is the Arecibo Message, the largest deliberate radio transmission ever released into space. The 3-minute message was launched from Puerto Rico and was aimed at the star cluster M13 near the edge of the Milky Way, approximately 21,000 light-years away. The signal was so strong that any SETI-detecting technology anywhere in the Milky Way would be able to detect the signal if the machine was as sensitive as the transmitter that sent the message and was searching at the correct frequency. The Arecibo Message included graphics of DNA, a stick figure drawing of a human, and the Arecibo telescope, among other things.

If the Arecibo Message differs from the content you would send to aliens, you are not alone. A company called Breakthrough Initiatives, a current SETI project, is hosting a contest called Breakthrough Message, an international competition to develop an active SETI message. As of now, the organization has no plans to send these messages, but only wishes to spark debate about what would be appropriate to send and what would be representative of Earth and Earthlings. Although the competition has not yet been launched, the organization has stated that the winner of the contest will receive a $1 million prize.

But what will happen if we do find aliens? Will civilians panic as if this was another War of the Worlds?

To ensure that any findings are approached in a calm and logical way, various SETI projects have agreed upon a Post-Detection Protocol. This protocol is updated periodically, and the latest version was agreed upon by SETI project leaders and the International Academy of Astronautics (IAA) in 2010. The Protocol mandates that all SETI projects be conducted transparently. Any detected signals that seem to be from ETI must first be verified by an outside institution; if and when the signal is confirmed, the discovery team must release a full report to the public and the scientific community. The signal data must be monitored, and if the received signal was a radio signal, the discovery team must work with World Administrative Radio Council to protect the related frequencies. Finally, before an active SETI return message is sent, there must be international agreement. This process will be overseen by the IAA SETI Permanent Study Group.

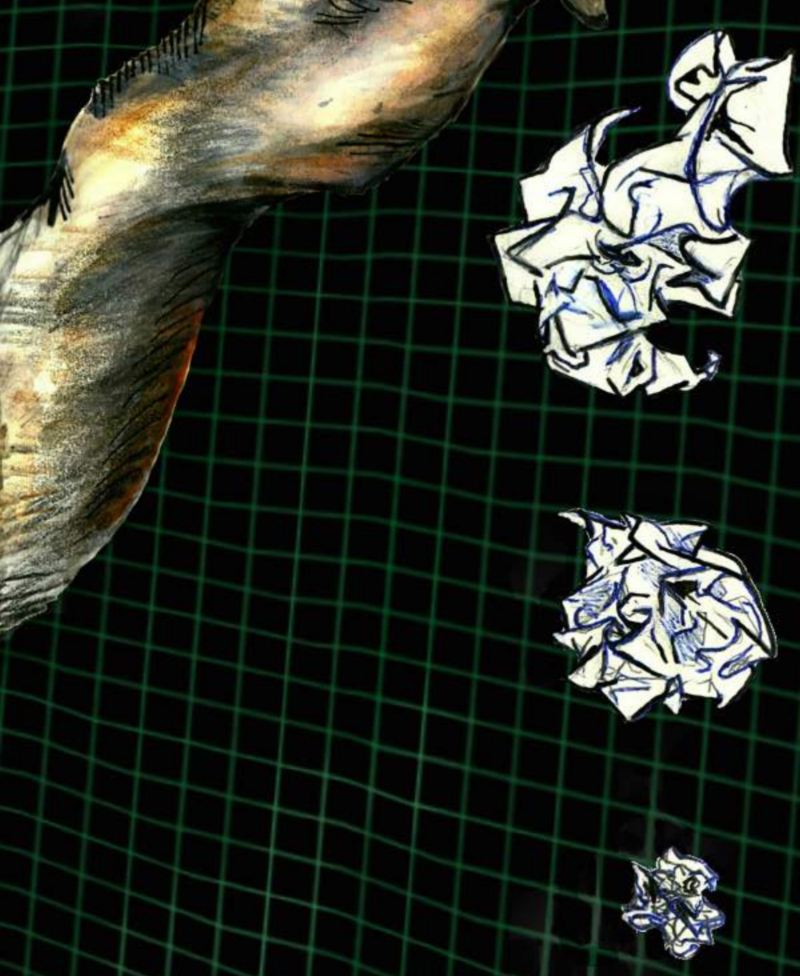
Are we alone in the universe? Or could we have neighbors, possibly even in our galaxy that are not only living, but intelligent enough to build a civilization and transmission devices? This idea may seem far-fetched, but some of the field's top minds believe that ETI is not only a possibility, but a reality. For them the question is not will we find extraterrestrials, but what will we say when we do find them?

The Big Bang

13.8 Billion Years Ago

At the beginning of time,13.8 billion years ago, all the matter and energy of the known universe was contained within an infinitesimal fraction of space. One trillionth of the size of the point of a pin, this object did not occupy a location in the universe, but rather was the entirety of the universe. It was not a where, but a when. That is, until it exploded outward with monumental force. From zero to 10-43 seconds after the Big Bang, conditions were so extreme that the forces that govern the universe—gravity, electromagnetism, strong interaction, and weak interaction—were unified and melded into one. This is the known as the Planck Epoch, the very first moment of the universe.

From then on out, in intervals of fractions of a second, the universe began to expand and cool. With this cooling the fundamental forces of space and time began to be shed and separate from one another, commencing their governance of the particles that were beginning to take shape. These bits and pieces of the early universe were rapidly forming, collapsing, and colliding in the restricted space. Suddenly, the strong interaction force separated from the electroweak (combination of electromagnetism and weak) force, thereby releasing a gargantuan amount of energy. In response to this further surge the universe's rate of expansion increased exponentially, its contents scattering forth with tremendous velocity. The dispersion of these particles across an increasingly vast space provided them with the opportunity to form into the subatomic particles that would become the bedrock of the known universe.

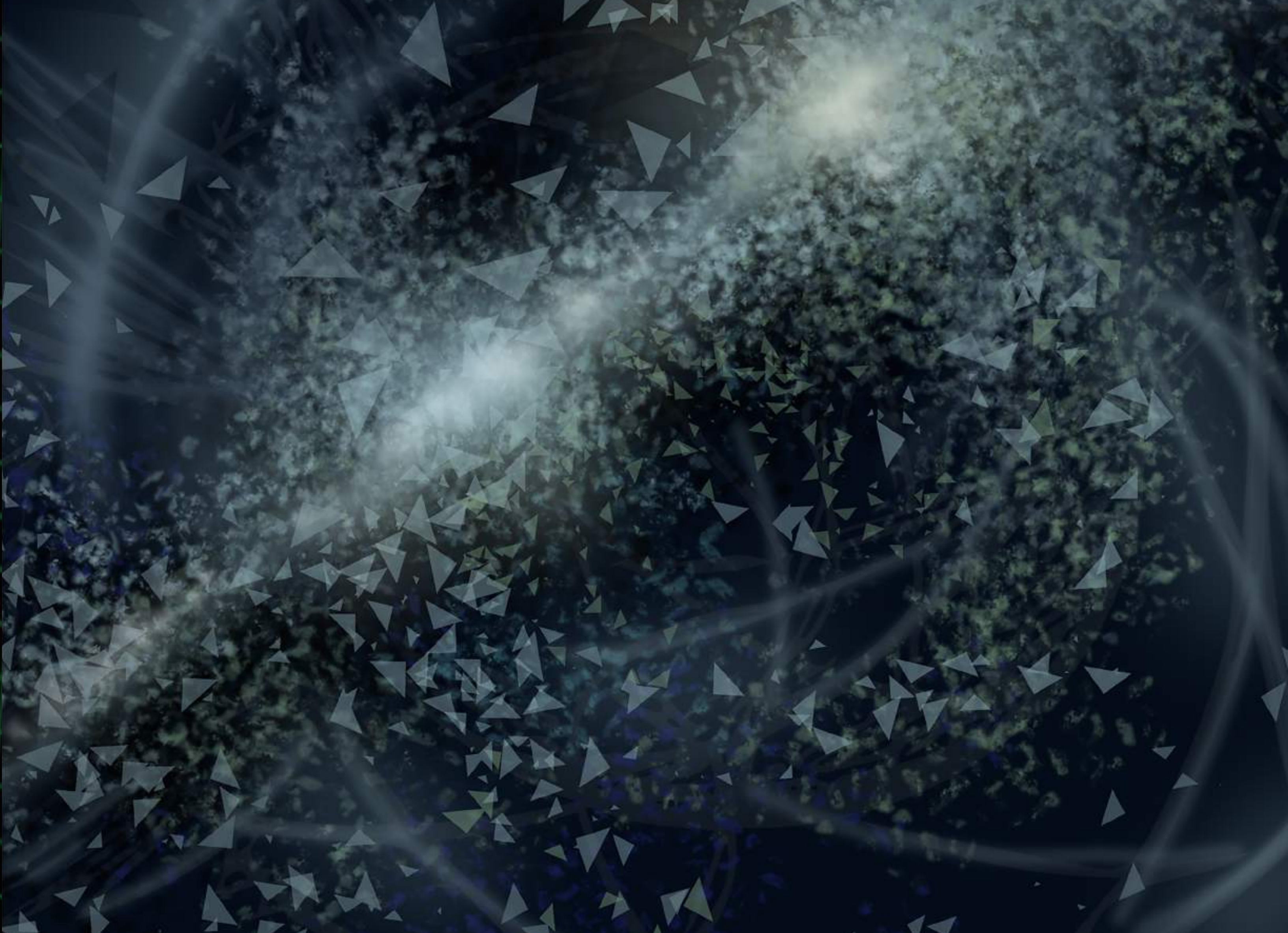


Recombination

377,000 Years After the Big Bang

When the expansion of the universe gradually slowed, freely distributed electrons and protons came together to form the first stable element: hydrogen. The advent of hydrogen, driven by the expansion and subsequent cooling of the universe, marked an important milestone in history of the universe. This new dawn was ushered in by a new particle: the photon. Photons, which before had been coupled with electrons and protons in a primordial soup of particles, ceased to be in a state of perpetual collision and followed their natural trajectory: out.

For the first time in history, there existed light as we experience it today. This light has become known as the cosmic microwave background, a remnant of an ancient epoch. While a normal, visible spectrum telescope detects only an expanse of darkness between celestial bodies, a radio telescope, sufficiently sensitive to detect even meager microwave radiation, can identify a faint glow that is not associated with stars or galaxies. This radiation, settled like a blanket over the entire universe, is the cosmic microwave background, the oldest light in the universe.



Reionization

13.7 Billion Years Ago

The early universe, then just 150 million years old, was awash with neutral hydrogen nuclei. They formed from the protons and electrons that, because of the high temperature of the universe, were previously unbound particles. Now that the universe had achieved physical substance gravity could begin to play a more prominent role. Clouds of nuclei began to form as atoms were pulled together into ever-denser objects. These early objects became massive and radiated tremendous amounts of energy, thereby ionizing the universe and converting matter into plasma quite similar to that which existed at the beginning. However, these isolated pockets of activity were scattered across a vast emptiness.

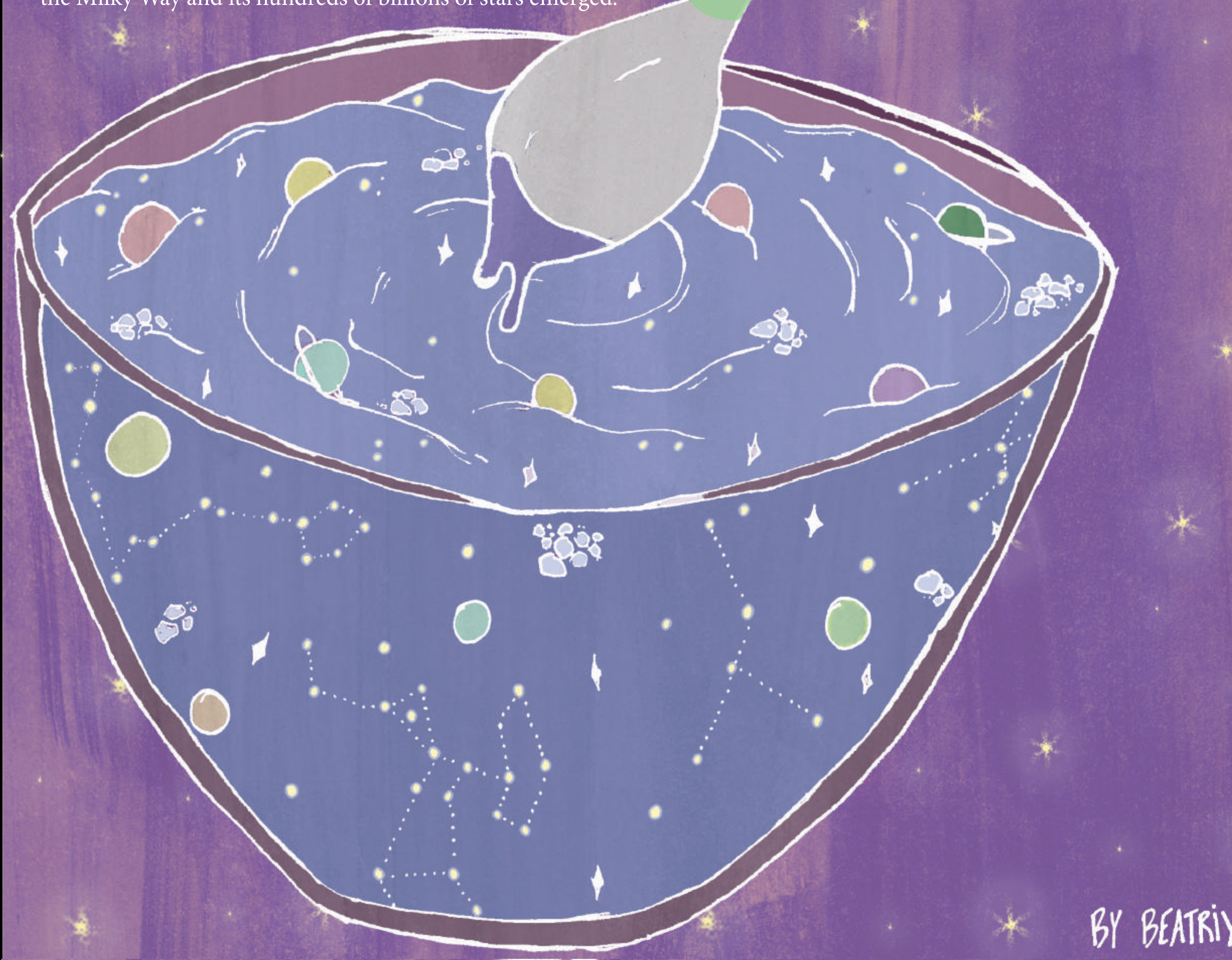
While it remains uncertain which objects provided the photons that reionized the universe, there are several likely candidates. First among these are dwarf galaxies, small galaxies composed of mere billions of stars (our own galaxy, the Milky Way, has over 100 billion). Because of their small size, dwarf galaxies are easily influenced by larger galaxies which, when they pass each other, can cause the former to warp, tear, and merge with the latter. This merging may produce a quasar, the next candidate for reionization energy. These active galactic nuclei are massive black holes that consume matter at an incredible rate. The friction generated by the matter being ripped and torn as it circles the black hole produces intense radiation. Being just beyond the point at which light can no longer escape—the event horizon—the radiation streams outward in a condensed jet of incredible luminosity. It is within this chaotic environment that our own galaxy began to form.

The Milky Way

13.2 Billion Years Ago

In the universe there exist three forms of energy: matter, dark matter, and dark energy. The first, and far less abundant, is of the type that we interact with every day. This is the stuff of neutrinos and leptons, protons and neutrons, atoms, compounds, molecules, organisms, oceans, and ice hockey arenas. It can be compressed to form solid molecular structures or diffused over great distances as a gas. Next is dark matter, a theoretical substance the existence of which is based on indirect observation. Its properties are inferred from its various gravitational effects upon visible matter. The third and most common form of energy is dark energy. It is hypothesized that dark energy accounts for 68% of all energy in the universe and permeates all space. Its existence was first proposed to explain the acceleration of the universe's expansion, now being the widely accepted cause thereof.

In order to create a galaxy, the cosmic conditions have to be just right. In the early universe, galaxies were primarily composed of gas and dark matter. As such, there were very few stars. As galaxies gained mass (normally by merging with smaller galaxies), the even distribution of matter and dark matter began to shift. Dark matter was relegated to the outskirts of emerging galaxies as gas accelerated inward. The condensed gas began orbiting the center of the new galaxy to become a very thin, rapidly rotating disk. As the spiraling arms funnel gas into the center of the young galaxy, the inner point becomes a dense, bar-shaped nuclei, operating as a galactic nursery that fosters stars. It is from such a beginning that the Milky Way and its hundreds of billions of stars emerged.

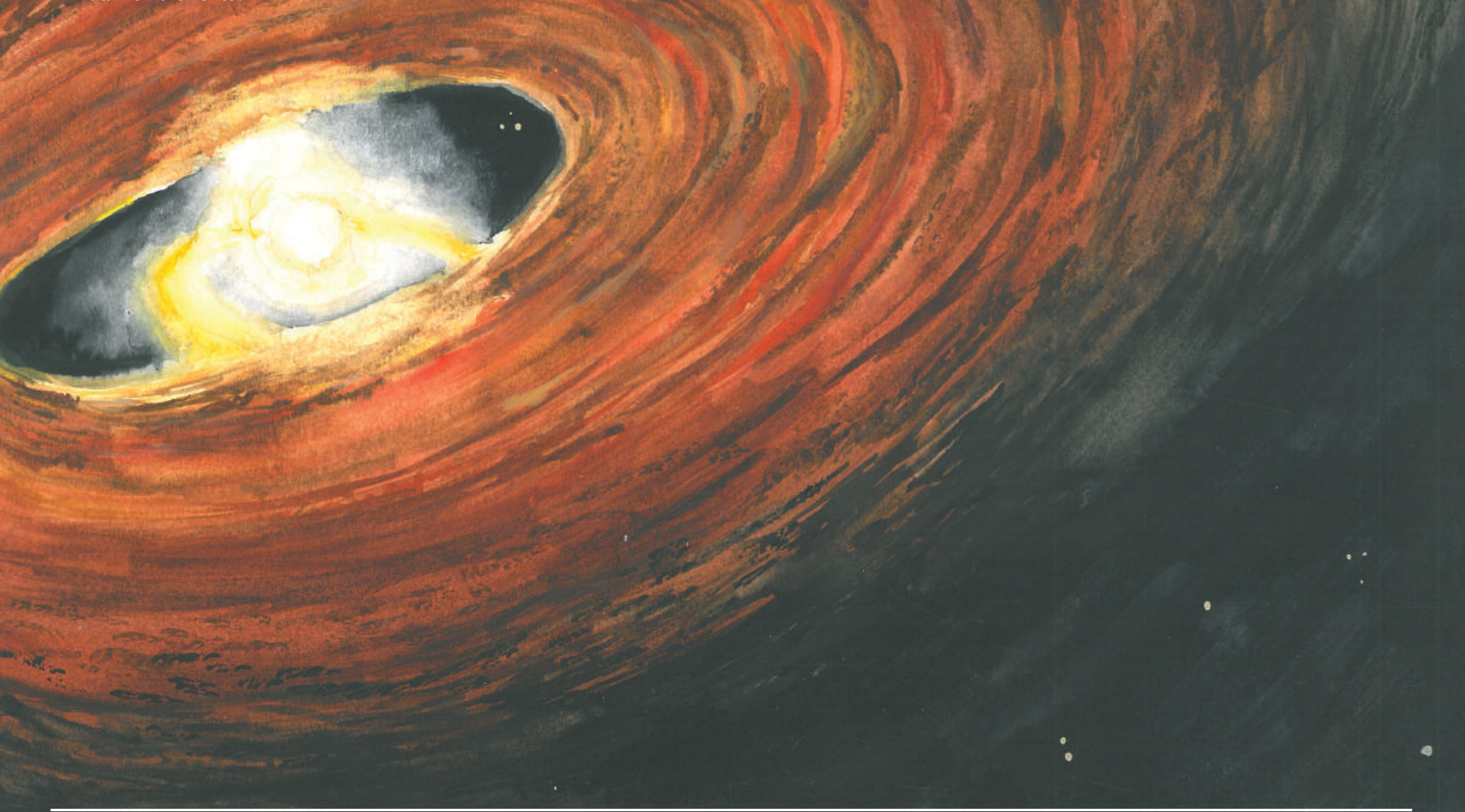


The Solar System

4.6 Billion Years Ago

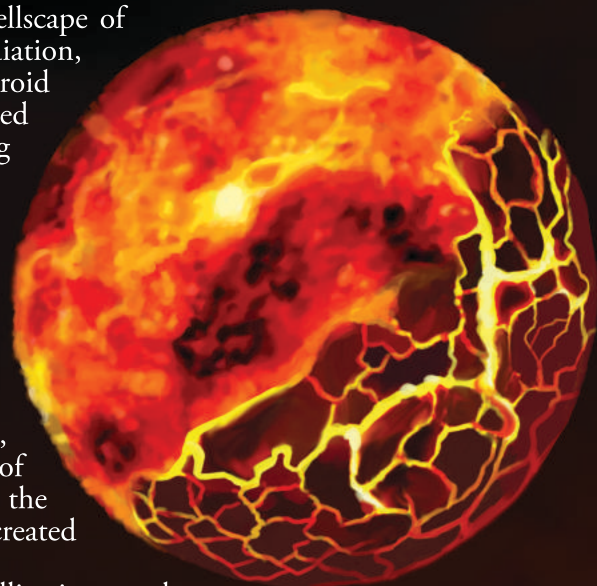
Our solar system resides in the Orion Arm, a minor spiral arm of the Milky Way. At a distance of 25,000-28,000 light-years from the Galactic Centre, it completes one revolution every 225-500 million years. 4.6 billion years ago all the matter that composes our sun and planets was distributed over a vast space. This molecular cloud was formed of primarily hydrogen, some helium, and a small collection of heavier elements fused by earlier generations of stars. It is thought that a shock wave generated by the supernova of a local star caused the cloud to ripple and fragment into over-dense regions, thus triggering the formation process. As a single fragment collapsed under its gravity, it drew in surrounding matter and contracted. As this occurred, a rotating disk of matter formed, spinning faster as its size decreased and its density increased. This process is very similar to the way in which a figure skater may increase the speed of their spin by drawing in their arms, a phenomenon known as the conservation of angular momentum. For our sun, colliding atoms began generating heat as competing forces caused a flattening of the nebula into a spinning protoplanetary disc. Once this disc became sufficiently dense it ignited, giving birth to a protostar. It was thus that our sun was born.

Within the orbiting tendrils of dust and gas, planets began to emerge. Gradually formed from orbiting dust grains, hunks of rock increased by centimeters a year over the next few million years. Around 100,000 years after the sun formed, the solar nebula was nearly out of dust. In its place orbited terrestrial embryos about 0.05 Earth masses. Through subsequent collisions and mergers, these objects would grew to become Mercury, Venus, Earth and Mars. Further influence of gravity and rotational forces transplanted them into their current orbits.



The Earth

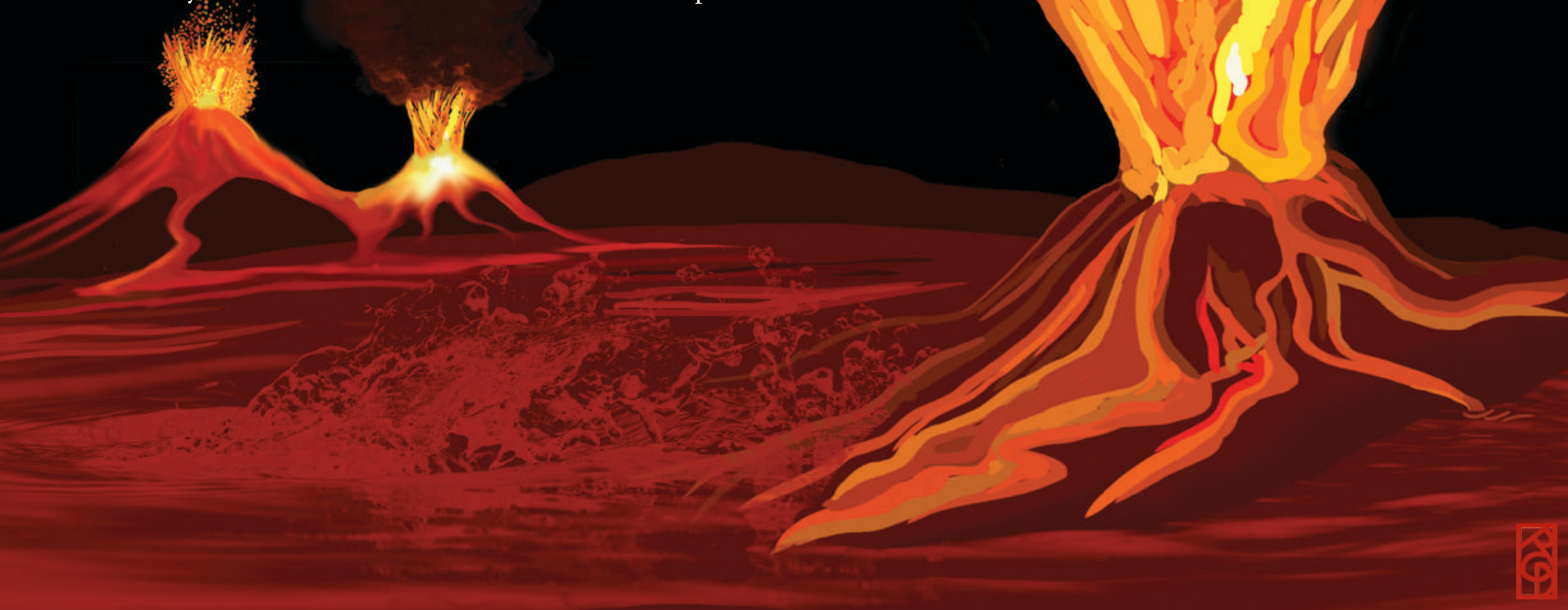
4.4 Billion Years Ago

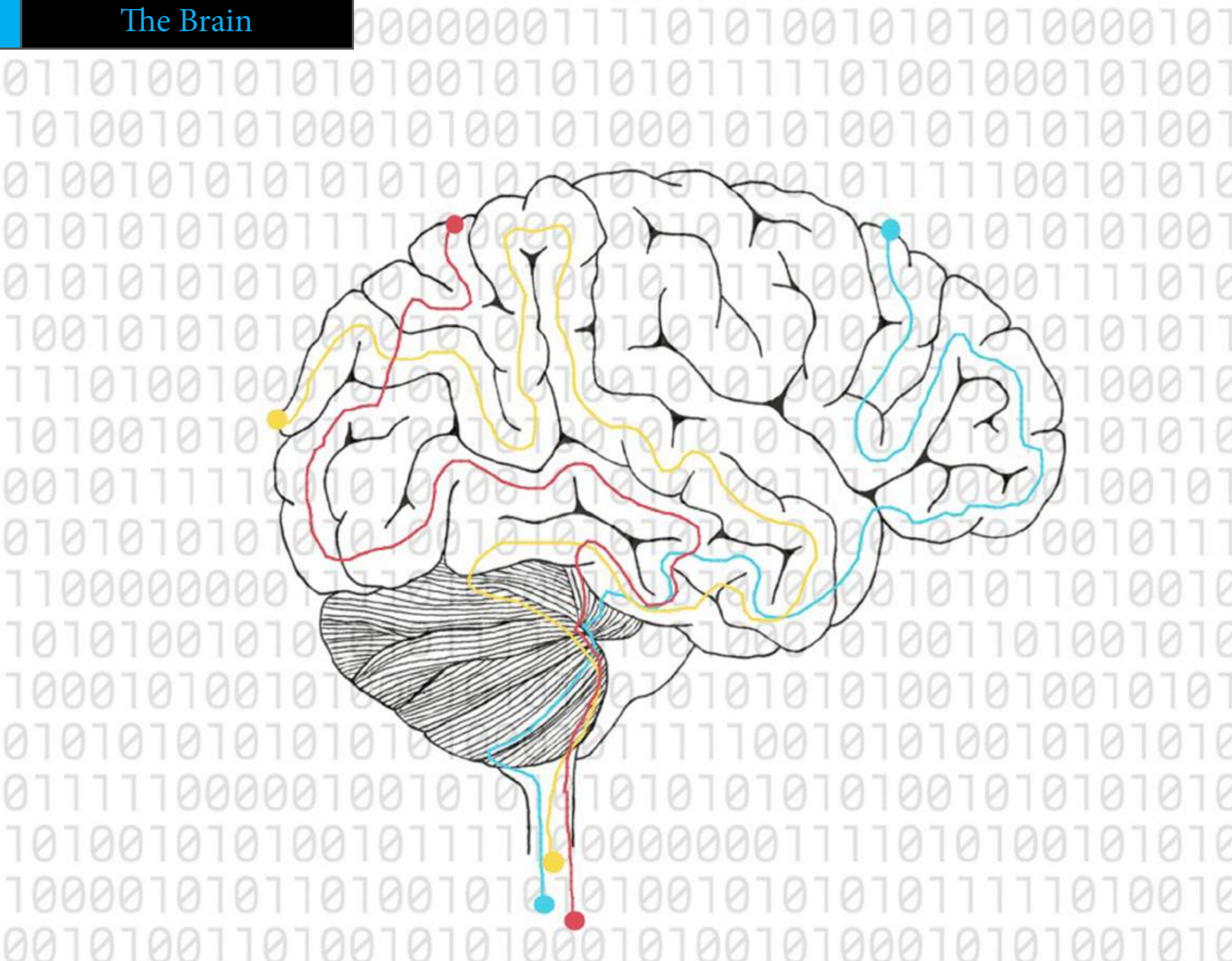


The early Earth was a hellscape of molten earth, solar radiation, and frequent asteroid collisions. Appropriately termed the Hadean Eon, this fledgling plane was totally inhospitable to complex life. Yet, even at this early date, liquid oceans existed on the surface. The evidence for water comes in the form of 4.4 billion year old zircon crystals that show indications of contact with water. It has been theorized that these oceans, despite a surface temperature of 230 °C, were made possible by the same protoplanet impact that created the moon.

Earth's only natural satellite is several times larger than any other satellite in the solar system. Rocks from its surface, courtesy of the Apollo program, show that not only is the Moon as old as the Earth, but it displays the same relative abundance of oxygen isotopes. Furthermore, Earth's spin and the Moon's orbit have similar orientations. These and other evidence support the theory that the Moon was formed after an indirect impact with an astronomical body the size of Mars known as Theia. Named after the Greek Titan and mother to the goddess of the Moon, the collision with Theia jettisoned chunks of the Earth's mantle into its own orbit. Eventually this debris merged to form a spherical body: the Moon.

The early atmosphere came into being at the same time the Moon was formed. The impact of Theia vaporized large quantities of rock and water that formed into a heavy atmosphere that shrouded the earth. Over the course of several thousand years, the dust condensed, settled, and left behind a heavy curtain of CO_2, which was dense enough to exert a considerable atmospheric pressure, thereby preventing the oceans below from vaporizing despite the heat. Yet, this early atmosphere was devoid of the oxygen that would eventually form the ozone layer and prevent harmful ultraviolet light from bombarding the surface. Under these conditions, it would be several billions years before the Earth would become a hospitable environment.





The Human Design

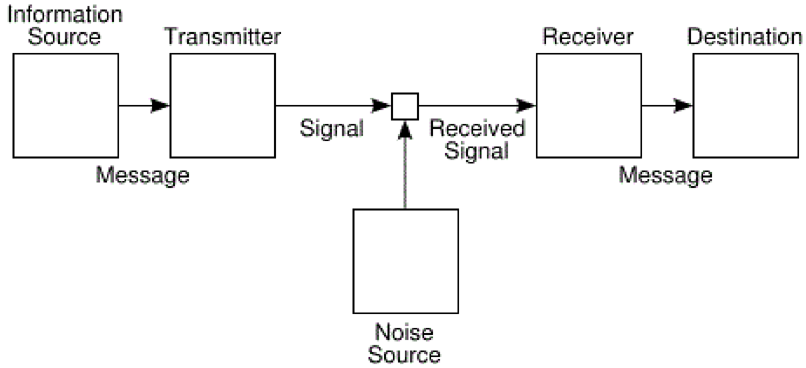
How Supercomputers Reveal the Secrets of the Mind

By Emma Hahn
Artwork by Caroline Edwards

Every day, college students flip open their laptops to scroll through favorite websites, unfinished essays, and countless unread emails. Most students think about the computers they use as direct extensions of their actions, outputting information as if they were just writing on paper. In reality, users' physical actions cause the machines to send enormous amounts of information through tiny processors that go through complex procedures to create the projected image that pops up on the screen. In this way, both our minds and the computers we manipulate filter and transform data in a very similar fashion. As a result of this understanding, it is becoming increasingly clear that human cognition and computation are inherently linked—if not complementary—in theoretical cognitive science research around the globe.

The complex processes that underlie human cognition from a molecular and sensory point of view are still not fully understood in the way that the components of a computer are understood in the context of the whole system. Therefore, a large part of neuroscience research today revolves around delineation of which anatomical portions of the brain allow us to move through the world in the way that we do through specific perceptions and resulting actions. Other research, however, is devoted to the use and manipulation of intricate computer programs that simulate our mental processes for us. This research is particularly compelling because it provides a basis for some expansive projects going on around the world right now. The history of development and connection of these projects is fascinating, and has allowed us to delve into complex questions of how extensive a computational reduction of the human mind is appropriate and efficient for our modern goals of discovery in cognitive science.

One example is the Blue Brain Project, an attempt to precisely reconstruct the brain computationally at Ecole polytechnique fédérale de Lausanne in Switzerland. The Blue Brain Project was controversial from the start—its initial results were often insignificant and convoluted, and with the enormous amount of money being poured into the project, it seemed like a bit of a waste. It was created by neuroscientist Henry Markram in 2005 and failed to live up to the standards of scholars in the



Shannon's Model of Information Theory
Claude Shannon, "A Mathematical Theory of Communication", page 3

cognitive science field. Many other scientists believe that using the utmost precision in modeling neural processing is too complicated and inefficient to truly understand the brain. They also weren't afraid of expressing that fact publically, even writing petitions condemning the project. With billions of neurons made of billions of proteins, and 60-100 different types of neurotransmitters all in a single brain, it seems excessive to some to create replicas of every possible outcome of every possible input and response. However, the researchers at Blue Brain pressed on, despite calls to widen their scope and look at decision-making from a simpler point of view.

A similar large-scale project that avoided some of these criticisms is the Allen Institute for Brain Science. Paul Allen, co-founder of Microsoft, created the Allen Institute in Seattle, Washington in 2003 in an attempt to develop systems that map out the human brain's anatomy and functions. The Allen Institute was different from Blue Brain in that it started off with a wider scope of brain reconstruction. Less focused on particular neurons or pathways, those at the Allen Institute hoped to examine the brain from, "the smallest molecular scale to the level of the entire system." This approach is much more focused on the holistic nature of the entire neurological system than the specific mechanics of each and every neurological pathway, as examined at Blue Brain.

The Allen Institute and the Blue Brain Project formed a partnership in March of 2016, further extending our ability to dissect the convoluted systems present in human decision-making processes. Because these two organizations developed with very different approaches to studying the mind through computation, the nature of their joint effort is all the more impactful and important. The partnership between the two focuses on issues that allow us to meld together the simple and the complex when it comes to the brain. One way to understand the full impact of this research is to look back at how their goals were created in the first place.

It started with psychological research, the first truly scientific research in the sense that written observations, a standard method of analysis, and regular tests of validity were required. The two big camps that split the field were the behaviorists and the cognitivists. A common metaphor for how to distinguish between the two is the "black box" metaphor. The box was a theory of human consciousness first used around 1945, when the behaviorist thought that dominated the psychological field for the first half of the 20th century was just beginning to wane.

Under this theory, environmental stimuli represented inputs into the black box—or the human mind—and outputs from the black box represented human behavior. Behaviorists saw the black box as closed and opaque, and thought that behavioral stimuli and responses were the only sources of information that researchers could use to conclusions about the human thought process. Everything inside the box was dark and unknown. Cognitivists, on the other hand, treated the situation inside the box—cognition, or the human thought process—as the most relevant piece of information in constructing a holistic picture of what came out of the box. The majority of psychologists eventually embraced cognitivist thinking over behaviorist thinking in a period of time after the 1950s known as the cognitive revolution, which pushed the mind rather than solely its inputs and outputs, to the forefront of research.

This shift into studying cognition led to a new scope of research that prospered after Claude Shannon, a mathematician, patented the concept of Information Theory in 1948. After working as a cryptologist during World War II, Shannon wanted to prove the inherent connections between mathematics and the natural world, with the growing field of technology during wartime as his foundation. The main turnout of his theory was a model that depicted the way information is processed through any format: mind, brain, computer, robot, and numerous other possibilities. This theory therefore set the standard for how information is processed in psychology, neuroscience, computer science, electrical engineering, and a number of other fields today. After this development, it was easy to see how the processing of information laid the groundwork for the creation of enterprises like the Allen Institute and Blue Brain Project.

An example of what is being worked on in conjunction by the two organizations is the modeling of simple visual orientation neurons, also called simple cells, in the brain. These neurons allow us to visualize our surroundings through the compilation of all of the lines of different orientations in our visual field, with each neurons representing a specific orientation. While the discovery of simple cells by Torsten Wiesel and David Hubel occurred in the late 1950s, our understanding of them was still limited until researchers at the Allen Institute fully reconstructed simple cells in mice. This success was only possible with a computational algorithm developed at Blue Brain. Additionally, because both organizations also act on an "open science" policy, these simple cell models are now free and available to public and private institutions alike. Therefore, professionals in any field can benefit from this collaborative effort in a way that would have never been possible before. This process itself sets a standard for information exchange in which a theoretical reconstructed human brain—and therefore human—is much more realistically attainable.

In our modern world, though, humans can't be interchanged with computers and machines, and vice versa. It is, however, easy to see that we do have analogous ways of behaving. We know now that students don't use laptops like they use pens, and it is because of our similar way of processing messages from our environment. These similarities have been enough to generate undertakings like the Blue Brain Project and Allen Institute. In the years to come, projects such as these will probably be able to reduce certain decision-making methods to one-line codes. Other cognitive processes will be too convoluted and complex for even their powerful technological systems to dissect. However, both approaches are valuable and influential pursuits that will transform the way we look at human behavior for a long time to come.

Pain on the Brain

Theories Over the Ages

By Oluwadamilare Ogunjimi
Artwork by Eva Bednarski

Pain. With finals quickly approaching, this is a sensation that we, as Oberlin students, are all very familiar with. For many centuries, humankind has tried to determine just what pain is and how we feel it. The three historically prevalent theories on how we process pain that we'll be looking at are Renee Descartes' Specificity Theory; Canadian psychologist Ronald Melzack and British neuroscientist Patrick David Wall's Gate-Control Theory of Pain, the current leading paradigm; and Melzack's new theory, one that solved all the questions that the Specificity theory and the Gate-Control theory could not: the neuromatrix.

During the 17th century, Renee Descartes presented to the world the Specificity Theory of pain. Within this theory, every area of the body with the sense of touch, or a tactile modality, has several dedicated neural pathways. There is a different pathway/combination of pathways for every sensation, including pain. When one of these areas touches something, there is a mechanical stimulus which must overcome a low threshold to activate nearby mechanoreceptors, meaning that it doesn't take much to activate these mechanoreceptors. These primary mechanoreceptors project the stimuli to secondary mechanoreceptors in the spinal cord or brain stem, depending on where the primary mechanoreceptors, and thus the initial stimuli, are located. The secondary mechanoreceptors project the stimuli to "higher" mechanoreceptors in the brain. In the brain, the "higher" mechanoreceptors translate the stimuli into the appropriate sensation, such as pain. This movement of the stimuli from mechanoreceptor to mechanoreceptor is much like a relay race, in which the signal encoding the stimuli is a baton and each mechanoreceptor is a runner. When talking about pain, the mechanoreceptors are referred to as nociceptors and the mechanical stimulus is a noxious stimulus, leading to the noxious experience that we call pain.

Descartes's Specificity Theory is relatively simple and makes a good distinction. It lays a clear-cut line between nociception, the nerves' transduction of noxious stimuli (the stimuli's movement from the initial point of injury, through the nerves, to the brain), and the brain's perception of pain (the noxious experience). Despite this distinction, the Specificity Theory also makes it seem like the brain just passively receives, translates, and processes any and every tactile stimulus. It belittles the brain's role in the experience of pain. It neglects our ability to numb a pain by distracting ourselves until we forget that it's even there. It doesn't recognize the many cases of chronic pain syndromes that include very real pain without an initial injury. It doesn't even take into consideration the phenomenon of phantom limb pain.

Recognizing the brain's vital role in the noxious experience was of great concern to Melzack and Wall. They realized that there is some type of filtering of stimuli that prevents the brain from just translating and processing every noxious stimulus it receives. To address this concern, they developed the Gate-Control Theory of pain. As the name suggests, within our nervous system is a "gate." This gate is the substansia gelatinosa, located in the dorsal horn. The brain is connected to this gate by way of large fibers. These large fibers send large signals to the gate, telling it to "close." Small fibers connect the gate to the peripheral nervous system. These small fibers carry small signals that tell the gate to "open" when there is an injury. When there is an injury, there need to be enough small signals from the peripheral nervous system to overpower the large signals coming from the brain to open the gate. A more traumatic injury leads to more small fiber signals, not only opening the gate but also leading to a more painful experience. Small fibers also exist in the central nervous system, allowing for pain to be felt from stimuli that originate from injuries in the central nervous system (i.e. the spine and brain).

Unlike the Specificity Theory, the Gate-Control Theory gives the brain a more active role in nociception. Ideally, the brain can send more large fiber signals to reclose an already open "gate." Despite this added insight, the Gate-Control Theory is still based on the assumption that pain requires an initial injury. It still overlooks cases where patients feel very real pain that has no associated initial injury, such as in chronic pain disorders and patients with phantom limb pain. Atul Gawande, in his book *Complications*, refers to a patient who suffers from severe back pains; however, no medical test has revealed anything out of the ordinary in his spine, lower back, or the rest of his body. The Gate-Control Theory provides no answer for what is going on in such cases.

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To pick up the Gate-Control Theory's slack, Melzack developed yet another pain system theory in 1993. This theory is currently the newest and most up-to-date (although the literature suggests that it is still incomplete). This system is known as the neuromatrix. The theory behind the neuromatrix is that the body is a unity, a single network that identifies itself as "self" and everything else (i.e. other people and the environment) as "other." This feeling of unity comes from the brain and can't come from the peripheral nervous system or the spine. Melzack suggests that these body-self processes are genetic in origin but are shaped by one's environment. These body-self processes occur in the neuromatrix, a series of neural loops between the thalamus and the cortex and between the cortex and the limbic system. The processing and nerve impulses that occur in the neuromatrix are called the neurosignature. Within the brain is a sentient neural hub that turns the neurosignature into experiences, or the flow of awareness. There is, within the neuromatrix, the active neuromatrix, which provides us with the sensation of proprioception, a constant awareness of where our limbs are located relative to the rest of our body. Active neuromatrices provides patterns of movements that lead to certain goals. Melzack explains phantom limb pain as an active neuromatrix trying to send or receive signals to or from the amputation site. These signals grow in strength until it creates a burning sensation. Cramping is supposedly the result of an action neuromodule trying so hard to move the now absent muscles that the output signal becomes a cramping pain. Within the Neuromatrix Theory, brain processes are usually initiated by inputs, but can also act without any inputs. In regards to pain, this statement means that pain usually comes from an initial injury, but the brain is perfectly capable of creating pain on its own.

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Although the Neuromatrix Theory requires further testing and more detail, it has managed to answer every available question that its predecessors could not. The brain is a powerful thing, a sentient neural hub that can do whatever it wants, whenever it wants. It can cause pain for no apparent reason or it can simply stop feeling pain. Maybe Melzack has given us Obies a way to escape the pain of finals.

Nail Polish

An Alternative War Paint

By Joy Udoh
Artwork by Adina Johnson

In a world where products are created with increased efficiency for communication, beauty, entertainment, and much more, we often forget that they are created through sophisticated processes based on the chemistry behind their components; nail polish is one of these products. Whenever a person needs a boost in their mood or confidence, nail polish is often a reliable source for this; it is a modern day war paint that evokes strength and assertiveness in people who use it.

Nail polishes are lacquers applied to the fingernails and toenails that are water and chip resistant. They come in numerous colors and are appreciated for their variety and ease of application. They were initially used to protect the nails or hide their defects and date back to the Bronze Age, when henna was obtained from the powder of dried leaves and used for nail decoration in India. This spread through Mesopotamia, China, and Egypt, and then evolved to become a mix of crystal, malachite, and sulfur powders.

The Chinese later used red nail polish as a method of distinguishing people of the ruling class from the general population. From China, red nail polish spread across the Middle East and Northern Africa where it was extensively used in Egypt. Red was used for royalty only — the stronger the shade, the more power an individual held. The lower classes were allowed to color their nails but were only permitted to use pale colors. Through the 18th to 20th centuries, nail polish became more common among women.

The methods of creating these lacquers have evolved over the centuries. From dyes to powders to cream polishes that were buffed onto the nails with a cloth, many creative ways of adorning the nails were formed before nitrocellulose—a key ingredient in modern nail polish—was introduced.

There is no single formula for nail polish. However, it consists of numerous basic components that make it easy to quickly apply to and remove from the nail. Chemically, it is considered a suspension product, since the particles are held in a solvent. This is why the components settle over a long period of time and the bottle has to be shaken before application for the best finish. One of the main components of modern nail polish, nitrocellulose or cellulose nitrate, was discovered during World War I. Nitrocellulose is a flammable substance that is the main ingredient in gunpowder. In nail polish, it is dissolved in a solvent like butyl or ethyl acetate and functions as a film that forms when the acetate solvent evaporates — this is what we smell when applying it. The solvents make it easy for the polish to be spread smoothly on the nail. Since nitrocellulose adheres poorly to the nail, resins are used to make the film adhere to the nail bed. They add gloss and hardness to the film of the nail polish. To add flexibility and reduce the chance of chipping, plasticizers like camphor are added, which link to polymer chains and increase the distance between chains.

Additionally, a large variety of chemicals known as pigments give nail polishes their distinctive colors. Some pigments include mica, which gives a shimmery look; titanium dioxide, which increases the opacity of the polish; and ferric ammonium ferrocyanide, which is mainly used as a blue pigment. These pigments are chosen based on how well they mix with the solvents involved. Finally, additional ingredients are added to the polish depending on the main feature that a particular brand is trying to sell. For example, quick-drying nail polish contains more solvent and evaporates more quickly, reducing the drying time.

Over the years, innovations like the fast-drying nail polish have been formulated for people on the go who don't have time to wait for their nails to dry. Another innovation that caters to customers' needs is gel nail polish, which is currently one of the most popular beauty breakthroughs. The biggest appeal of gel nail polish is the fact that it remains perfect for at least two weeks without chipping and doesn't require any drying time. The Sally Hansen gel nail polish formula doesn't require the lacquer to be cured under UV light like most gel manicures; instead, it contains an oligomer, which serves as the resin and works in conjunction with the top coat, which includes a photoinitiator. The photoinitiator activates a bond between the nail polish and top coat which cures the formula in natural light so it dries quickly without the use of a UV lamp.

Nail polish technology has been used for numerous applications over the years. Penlac Nail Lacquer Topical Solution 8% is a nail lacquer that has been tested and approved by the FDA as a treatment for mild to moderate cases of fungal infections in the nails. In this case, nail lacquer serves as the medium that the active ingredient, ciclopirox, is incorporated into. It sends ciclopirox into the nail bed, where the fungus is most active, through a transungual delivery system to fight the infection.

Recently, a group of four students at North Carolina State University in the Materials Science Engineering program created a nail polish that changes color when it comes in contact with a date rape drug. They branded their product as Undercover Colors and produced the formula to empower women so that they have another method of protecting themselves from sexual assault. These students took the concept of nail polish as war paint and applied it to situations in which women are most vulnerable. However, the creation of this prototype has been controversial and has received various negative responses from organizations that work to prevent rape and sexual assault. The main cause of concern has been the fact that this product doesn't solve the problem of rape or assault. Tara Culp-Ressler of ThinkProgress wrote in response that women already have to be very conscious of the way they dress and the company they keep. Now, they would have to remember to put on "anti-rape nail polish" and discreetly slip a finger into each drink as the night wears on. She believes that this only reinforces the pervasive rape culture in the society. Additionally, both women and men are victims of rape, which segues into the conversation of the perceptions of rape and gender.

Responses to the discovery of this application have been varied and have expanded the conversation on rape and the perceptions the society has about it. However, each reader and member of this conversation has a different perspective. What do you think?

Overall, nail polish is a powerful tool that isn't usually considered at its chemical level on a daily basis. Its applications are numerous and continuously expanding and changing. From early civilization to the present day, nail polish has been a beauty icon that has prevailed and will continue to do so in different ways in the future.

Moonshot for Cancer

The Language of Cancer Policy

By Nate Bohm-Levine

During his eighth and final State of the Union address, President Barack Obama announced plans to lead a "moonshot" effort against cancer. The mention was brief, almost an afterthought; you might have missed it if your mind had drifted off a bit in the hour-long speech. Yet amidst a speech on seven years of presidential accomplishments, it was one of the night's only clear policy proposals. Plus, explicit plans to address issues in science and health, especially coming straight from the president himself, are rare. Watching Obama say he would begin this "moonshot" was exciting; the words conjured images of the Apollo Space Program, the grand effort of the 1960s to put an American man on the moon. While grandiosity might draw skepticism, something in Obama's earnest tone suggested that these words held promise: "For the loved ones we've all lost, for the family we can still save, let's make American the country that cures cancer once and for all."

Seated to Obama's right, a knowing smile on his face, Vice President Joe Biden nodded. Biden had announced the "moonshot" plan himself three months prior. "It's personal for me," Biden said in a statement released during the State of the Union address. Cancer is indeed very personal for the vice president. For one, it is technically Biden's plan (Obama referred to Biden in his speech as the one in charge of "Mission Control," another throwback to the Apollo Missions). More importantly, however, Biden took on the plan following his own encounter with the disease—Biden's son Beau had been diagnosed with brain cancer in 2013 after an episode of "disorientation and weakness," as released in an official White House statement. After two years of relative remission, the cancer recurred and Beau was admitted to the Walter Reed Medical Center in Maryland. He died ten days later. As a result, the Biden-led "moonshot" plan is fueled with the vice president's passionate desire to eradicate the disease.

The plan is noble, if still relatively unclear. So far, the main goals of the plan are to increase funds available for research and encourage greater cooperation between scientists, who so often refrain from sharing their research, keeping their data in figurative silos. The idea is that these steps would lead to finding a cure for cancer. This is a vague and almost mythological goal—is a cure a treatment that will sustain life until old age? Is it the complete eradication of every single cancerous cell in the body? Immortal life? The dramatic connotations of the word "cure" make sense given the connotations of a moonshot—images of rocket launches and moonwalks are no less awe-inspiring than they were 50 years ago. But can we really compare the search for understanding and treating a complex disease to the effort to put a man on the moon?

> The image of a conquest appealed to non-academics. After all, cancer was an enemy of dramatic proportions, so why not treat it as such?

As Siddartha Mukherjee notes in his historical epic T*he Emperor of All Maladies*, Obama's State of the Union was not the first time such dramatic metaphors were used to talk about cancer. In 1971, Senators Ted Kennedy and Jacob Javits introduced a bill to the U.S. Senate with the goal of increasing funding for cancer research. This bill would have created a permanent institution known as the National Cancer Authority (NCA), bestowed with a freedom unprecedented for governmental institutions. In a time when the National Institutes of Health retained supreme power over scientific endeavors, the NCA would have been free to self-direct and pursue lines of research frowned upon by the so-called ivory tower of academia. The writers named the bill "The Conquest of Cancer Act." The image of a conquest appealed to non-academics. After all, cancer was an enemy of dramatic proportions, so why not treat it as such? When explained by the average cancer biologist, the disease can seem dry, almost boring: genetic mutations accumulate that alter cell machinery to induce hyper-proliferating, metastasizing cells. In contrast, metaphors remove this jargon and bring the technicalities to life. In one of the first attempts to link the moon landings and cancer cures, a popular advice columnist of the time wrote, "If this great country of ours can put a man on the moon, why can't we find a cure for cancer?" Metaphors hyper-simplify things, but they can also make the next steps clear to see. Conquest of cancer? Bring on the artillery. Moonshot? Fire up the engines—we're going to space, kids!

> "An all-out effort at this time would be like trying to land a man on the moon without knowing Newton's laws of gravity."
>
> -Sol Spiegelman, 1971

Yet metaphors also have the potential to obscure things to the point of confusion; simplification, while making complicated concepts manageable, often leads to the rabbit-hole of dead-ends, false promises, and misdirected resources. The former U.S. Secretary of Health Philip Lee, partly in response to the advice columnist's lunar comparisons, said, "Cancer is not simply an island waiting in isolation for a crash program to wipe it out. It is in no way comparable to [the Apollo program], which requires mainly the mobilization of money, men, and facilities to put together in one imposing package the scientific knowledge we already possess." At this point in history, the research into the cellular mechanisms underlying cancer was still in its infancy. Scientists had no real understanding of what made a cancer cell, well, a cancer cell. Had researchers possessed this knowledge, the so-called conquest would have been swift and cancer—our enemy—would have been easily flattened to the ground, razed and pillaged. Sol Spiegelman, a prominent cancer scientist of the time at Columbia University, brutally turned the moonshot metaphor on its head when he quipped, "An all-out effort at this time would be like trying to land a man on the moon without knowing Newton's laws of gravity." In short: details are important, sometimes.

Ultimately, the 1971 Senate bill passed, but its proponents felt they had failed. The NCA was implemented, but it was not autonomous, and its funds were much less than requested. For now, at least, there was no moonshot.

But what about today? Is a cure within our reach? Is now the time to start the moonshot? The secret to figuring out cancer is probably not just a simple matter of providing more money for research institutions and encouraging some sort of forced collaboration, though those things will certainly help. After all, there is no doubt that 2016 looks a whole lot different than 1971. Researchers have made incredible strides in delineating the specific biology of the cancer cell. Treatments have also vastly improved since the seventies, when the Conquest of Cancer Bill was first brought to Congress. So maybe we are ready now.

Regardless, the history and resurgence of the moonshot metaphor illustrates the interesting relationship between science and language. Academia can be frustrating to an outside observer, with its longwinded scientists and their almost comedic specificity. Why would we want to know the details of cell division if we cannot immediately use that information to help those in need? To an outsider, this can seem misdirected, but these cellular details are vital to understanding cancer, just as the details of designing spacecraft were to the moon landing missions. Perhaps one of the strengths of the Apollo Program was distilling these dull specifics into a simple, exciting question—how do we get to the moon? Metaphors will undoubtedly be needed to communicate cancer to the public and to our lawmakers, but so will a sensitive understanding of the cancerous cell. We need simplification for public support, but we need complexity in our research. We need a moonshot, but it must be a targeted one.

Casting Doubt

How the Product Defense Industry Manipulates Our Perception of Science

By Brooke Ortel

Seen from the air, Kivalina is little more than a tiny strip of sand dwarfed by the vast expanse of Arctic landscape and sea. But for approximately 400 Iñupiat residents, this tiny barrier island above the Arctic Circle is home. Pounded by storms and threatened by increased coastal erosion and the loss of protective sea ice, Kivalina is already experiencing the effects of climate change. Although Kivalina residents voted to relocate in 1992, so far they have been unable to secure the funding they need to move to a safer location. In her book *Kivalina: A Climate Change Story*, Christine Shearer chronicles the community's decision to challenge key drivers of climate change in the legal arena.

In 2008, Kivalina residents filed a lawsuit against 24 fossil fuel companies in the U.S. District Court for the Northern District of California, confronting the potent forces of government inaction and corporate manipulation of climate change science. They asserted that the defendants, including oil giants ExxonMobil, BP, and Shell, are "significant contributors of greenhouse gas emissions, exacerbating global warming and erosion in Kivalina, constituting a public nuisance under federal and state common law." The secondary claim targeted a subset of the defendant corporations, charging them with creating a false debate around the validity of climate change science. Although the lawsuit was ultimately unsuccessful in obtaining funding for relocation, it raised important questions about who should be held accountable for ensuring the safety of communities like Kivalina that are already feeling the effects of climate change.

Although the climate change story is new, the techniques used by the fossil fuel industry to cast doubt on the science threatening their profits are not. In her book, Shearer places the Kivalina lawsuit within a larger narrative that traces the development of the product defense industry (PDI) in conjunction with the historical efforts of asbestos, lead paint, and tobacco companies to create a false debate around scientific evidence showing their products were harmful. The product defense industry is comprised of lawyers, scientists, and public relations firms that industries enlist to deliberately shape how the public and policymakers perceive scientific evidence. Many of the same players instrumental in manufacturing doubt around these industries rallied to incite public doubt surrounding climate change science. Shearer's exposé of Kivalina's "climate change story" is about much more than climate change—it is about the calculated manipulation of science for corporate ends at the public's expense.

Shearer writes that the purpose of the product defense industry is to "delay and avoid government regulation, regardless of the costs to the public." These organizations use a powerful "discourse of doubt" to downplay potential health and environmental risks associated with particular industries and exaggerate the economic burden of regulation. Beginning with the asbestos industry, PDI has proved to be a powerful tool for protecting corporate interests. By shifting concerns about workers' health problems to a scientific debate about the acceptable levels of exposure to asbestos, industry leaders effectively cut the public out of the discussion of health hazards and manipulated the findings of researchers who were hard-pressed to find other sources of funding. During the 1920s and '30s, the asbestos industry financed research on the health impacts of asbestos dust, but suppressed the results, which would have jeopardized their profits. The public relations firm Hill & Knowlton became a fixture in PDI starting with its role in defending the public image of the asbestos industry, reappearing as other industries sought aid in shielding their products from scientific evidence and public scrutiny.

In response to a 1934 *Time* magazine article on the connection between lead exposure and learning disabilities, lead paint companies turned to Hill & Knowlton for assistance in countering the growing evidence for the harmful effects of lead. Hill & Knowlton's first action was to generate fraudulent paper on lead poisoning in children and then, post-writing stage, find scientists willing to claim authorship. Meanwhile, the Lead Industries Association, a trade group formed to promote a more favorable image of the industry, insisted that lead exposure only presented a health risk at high levels and placed the blame for childhood lead poisoning on poor parental supervision. Lead industry proponents also insisted that the use of tetraethyl lead in gasoline was safe because it was supposedly less toxic; this false rationale held for decades, until the 1960s, when overwhelming scientific evidence overturned the industry's invalid arguments.

A third wave of corporate dependence on PDI manifested in the tobacco industry's efforts to obscure the link between smoking and cancer, taking product defense to a new level. Once again, Hill & Knowlton played a central role in manufacturing doubt, establishing the Tobacco Industry Research Committee in 1954 and suggesting that the industry market filtered cigarettes and "low-tar" products as less injurious to health. In 1964, following a watershed report released by the surgeon general on the connection between smoking and cancer, a group of doctors affiliated with the tobacco industry testified before Congress that there was "no proof" that smoking actually posed a health risk. In response to a 1992 EPA report on secondhand smoke, the Tobacco Institute, a trade group, paid scientists to write letters to prominent scientific journals decrying the EPA's findings. In Kivalina, Shearer reports that internal documents revealed that the tobacco industry was "not just working to protect its own industry, but was also linking up with other industries to affect the national consciousness about science and risk." For instance, Philip Morris created a "national coalition to educate the media, the public, and public officials on the dangers of 'junk science'"—in other words, a foundation designed to debunk legitimate science that threatens corporate profits.

The fossil fuel industry has built on this legacy, creating an illusion of competing scientific perspectives in the climate change "debate." Two public figures in particular have played leading roles in the dispute over climate change science. Both S. Fred Singer, a physicist, and Frederick Seitz, former president of the National Academy of the Sciences, have repeatedly downplayed the scientific consensus on climate change, in some cases even citing false or nonexistent data to support their positions. Shearer points out that their actions "have been aided by U.S. media outlets that equate objectivity and balance with merely presenting different sides of an issue, even when one side is widespread scientific consensus and the other is a handful of industry-fueled contrarians, leading to measurable increases in U.S. public certainty." Seitz was responsible for the "Oregon Petition," which was designed to resemble a NAS report and listed scientists skeptical of global warming.

Such efforts to muddle the public and policymakers' perceptions of widely accepted climate change science persist at the expense of communities like *Kivalina*. In her book, Shearer quotes Kivalina resident David Frankson, who explains that, "people say global warming is not happening because they don't live our lives, or see our snow, our ice, how it's melting." Not only does the Kivalina community face physical hazards posed by climate change; they are also embroiled in a larger conflict over the corporate manipulation of science. While policymakers and the public entertain the "debate" about climate change kindled by the product defense industry, Kivalina residents experience climate change as a daily reality.

A Lexicon for the Anthropocene

Shifting Vocabulary in Rapidly Changing Climate

By Ally Fulton
Illustrated by Lauren Rhodes

Standing in front of the icy blue torrents of the Baker, one of Chile's largest rivers, we find ourselves in the middle of a global conflict over a proposal to build three hydroelectric dams. Here we meet Peter Hartmann, regional head of Chilean Friends of the Earth and an outspoken opponent of the dams, who places high value in the aesthetic ideal of wilderness. The negative impacts of the dams are clear: fertile land will likely be flooded, possibly displacing thousands of people; the weight of the water can cause earthquakes, and downstream flow may be reduced, which results in sediment backup and less fertile soils. Yet we also get a glimpse of the huge economic benefits that could lift many of Chile's poorest residents out of poverty, while creating new artificial wetland habitat to support countless bird species as well.

This is the scene Gaia Vince sets in her poignant narrative *Adventures in the Anthropocene: A Journey to the Heart of the Planet We Made*, which takes us into the heart of a big environmental issue thousands of miles away to show us the effects of our consumption on communities we may never have come into contact with otherwise. Through stories of her travels around the globe, often in poor communities, she shows how urgent it is that we, as an international community, renew awareness of our enormous amount of planetary might, one that necessitates "a quite extraordinary shift in perception, fundamentally toppling the scientific, cultural and religious philosophies that define our place in the world, in time and in relation to all other known life." Thousands of lives depend on these decisions, and we must make hard choices that involve sacrifice, whether that is cultural or economic. Vince examines the world through a lens that asks: are there narratives floating in the intellectual matrix of the worldly community that can generate systemic and structural change, and move us confidently as a human community into the future?

The Anthropocene refers to the newly proposed geologic epoch prompted by humanity's ever-growing influence on Earth's biosphere that will leave a lasting mark for centuries. The term was proposed by Nobel laureate Paul Crutzen, an atmospheric chemist who was struck by the erroneousness of the term Holocene—which defines the geologic epoch of the past 11,700 years—for describing the state of world at the turn of the millennium. A working group of geologists and stratigraphers was created in 2009 to decide if the Anthropocene could be scientifically labeled as a new epoch, and, if so, when it began. A report in *Science* that came out in early January of this year adamantly stated that the Anthropocene is functionally and stratigraphically distinct from the Holocene, a claim supported by examination of biological, climatic, and geochemical signatures of human life in sediments and ice cores. Current rock deposit samples are comprised of new minerals and rock types, which reflect the start of the Anthropocene epoch in the mid-20th century.

> Thousands of lives depend on these decisions, and we must make hard choices that involve sacrifice, whether that is cultural or economic.

From its inception, the Anthropocene has defied the sturdy bounds of academia. Instead it has been taken up by society at large: artists and writers, politicians and citizen scientists, sociologists and conservationists. And this is what gives the Anthropocene its potency—it is a term that challenges our general conceptions of planetary forces and asks us to take full responsibility for the tremendous and violent scale of change that has occurred throughout the past century and will continue to occur over the next hundreds of years. While scientific data has reiterated the looming presence of climate change and its devastating effects, these numbers, facts, and figures hold little emotional weight in terms of global response to the rise of this new, unfathomable geologic era. However, what the Anthropocene offers is a space that breaks down boundaries between the natural sciences and the humanities, a space for scientists, artists, politicians, urban gardeners, and school teachers alike to join together and initiate dialogue on the productive and revelatory power of seeing the world in an empathetic light that can adequately and creatively respond to the planetary changes on the horizon. In essence the term itself asks for new metaphors, narratives, and storylines, ones that show us that our language and ways of thinking about the world need to change to fit the Anthropocene. If we can reinvigorate and refurbish the hollow language of the Holocene into one that is compassionate, resonates from the depths of our directly lived experience, and pushes us a toward tackling the problems of the present with a gaze situated toward the future, perhaps we can enter the Anthropocene from a perspective that understands human interactions with chemical, biological, and physical systems, and accepts human-built infrastructure as natural.

The Anthropocene poses difficult questions that ask us to envision ourselves not only as human inhabitants of this moment, but also as inhabitants of a past that extends far behind us, and a future that rushes forward at a brisk clip. I turned to the Stanford University Blog "Generation Anthropocene" that claims to "cast its butterfly net as wide as possible to capture the conversations from this new age." Contributors to the site range from geologists and ecologists to historians and literary critics, all committed to tackling these environmental issues through the medium of storytelling. I began my search in the realm of Anthropocene podcasts with Ursula Heise's discussion on the narratives of environmentalism. She notes that facts are actually a lot fuzzier than our narratives suggest. Take biodiversity and conservation for example: scientists don't even have an agreed upon definition for the term 'species,' which makes confirming extinction a little abstract. But narrative images and metaphors can be used to make these fuzzy concepts, well, less fuzzy. A metaphor can take the lush landscape of a backyard garden, or the dry red rocky landscape of Zion National Park and make them culturally relevant because it ties the land to us as beings. Metaphors take the complicated numbers and figures of science and make them matter.

But are we to reconfigure old metaphors? Or do we need entirely new ones? Emma Marris, in the podcast "Hanging out in a rambunctious garden," suggests that our language and narratives must shift to looking forward, not backward, which proposes that we need newfangled metaphors. On top of that, our cultural relationship to nature must shift. American culture, especially, privileges a sense of solitude in the unbridled vistas and sweeping landscapes of the natural park and wilderness area aesthetic. Marris proposes that the view of the big family picnic, grilling hotdogs and hamburgers in the park as kids play in the grass, needs to be included in this larger view of relationships with nature. Natural places don't have to be pristine and part of the sublime to be worthy of our engagement with them. We must renew our view of the world to include a sense of interdependence in *all* places, the urban, rural,

wild, and human-constructed. If we can locate the certain specialness we find in natural areas beyond the prototypical wilderness reserve, we can begin to restore value in communities that are excluded from discussions about what we want our world to look like.

Ursula Heise also touches on how these cultural narratives and principles can shape the way that science is carried out. For instance, current research on conservation and biodiversity affects what research continues to be funded and drives scientists to study the same types of species (namely mammals and birds). The narratives that emerge from this popular scientific research diffuse into the general public and firmly shape general cultural attitudes toward pervasive problems such as conservation, climate change, and a myriad of other issues. Science is not completely conditioned by culture because it can modify, change, and correct cultural perspectives, but is not in and of itself entirely free from cultural contexts. However, as we've seen, scientific narratives of climate change have barely been translated into environmental policies, or even different ways of thinking about nature. Andrea Thompson's Climate Central article on the need for greenhouse gas reduction by 2050 cites that the Intergovernmental Panel on Climate Change (IPCC) doesn't provide discrete proposals for how the transition to renewable energy sources should be achieved. Additionally, the most recent IPCC report mentions: "Lifestyle and behavioral changes could reduce energy demand by up to 20 percent in the short terms and by up to 50 percent of present levels by mid-century." Perhaps cultural norms are our entry point into devising specific guidelines for the widespread use of renewable resources. The question remains: how can we take the new language emerging from the shallows of the Anthropocene and transform it into a lexicon teeming with ways to bring about these behavioral and cultural shifts?

In a preface to the recently released *Art in the Anthropocene,* the editors Heather David and Etienne Turpin offer a potential answer to this inquiry: the prevailing feeling of degradation and exhaustion brought about by climate change, biodiversity loss, etc. calls for fresh approaches to literary and artistic representation that work to incorporate ecological concepts and metaphors. One essay in this collection, titled "Cloud Writing," by Ada Smailbegovic, features the Blur Building in Yverdon-les-Bains, Switzerland, a metal structure that stands weightlessly in the water with a cloud clinging to its skeleton. She suggests that this linguistically devoid work of art is still able to write, or function rhetorically. This is because the cloud structure forms and reforms into wider and narrower, denser and looser, whiter and grayer configurations over the course of the day. A low hanging, heavy, grey cloud that masks the metal structure demands different descriptive vocabularies than a light billowy cloud hanging suspended in the air as if attached to an invisible string. In this way, the structure demands constantly shifting vocabularies to describe it. The Anthropocene calls for similar vocabularies because of the rate at which we are changing the Earth's biosphere. According the Environmental Protection Agency, a federal government agency tasked with preserving human health and the environment, northern hemisphere snow cover is anticipated to decrease 15 percent by 2100; ocean acidification could slow coral growth to almost 50 percent by 2050; and sea levels and global temperatures are projected to rise one to four feet, and 0.5 to 8 degrees Fahrenheit, respectively, by 2100. We must enact new policy changes immediately if we are to slow or reverse these global trends, and our vocabularies are at the forefront of making these changes possible.

And this can even be accomplished with the help of science. Leslie Chang's podcast "What is a Word?" questions how we talk, hear, and communicate. She speaks with Nicole Creanza, a post-doctoral researcher at Stanford studying the relationships between cultural evolution and genetic evolution through behavioral and linguistic analyses, to discuss how the spread of languages is closely aligned with the spread of human genes across the Earth. Language gives Creanza and her colleagues an understanding of the places where genes may not tell the complete story. If an observed linguistic pattern differs from archaeological or genetic evidence, they have to think about cultural transmission in a new way. In the context of the Anthropocene, as Chang suggests, you could argue that the development of human language led us into this new epoch. Our dazzlingly, complex societies and technologies wouldn't exist without our ability to speak with one another, within and between communities, as well as globally.

In Creanza's eyes, then, we have a built-in solution to our current cultural problem. To put this more into perspective, Robert Macfarlane, in his essay in *The Guardian* titled "Generation Anthropocene," offers the following: "Systemic in its structure, the Anthropocene charges us with systemic change." And it is because of this that the Anthropocene has inflicted a "massive jolt to the imagination," one that opens up rather than foreclosing progressive thought. Evolutionarily attuned to have a deep attachment to stories, perhaps this is where we must return. To move confidently into the future of the Anthropocene, we need vibrant metaphors, narratives, and stories that speak directly from our lived experience—that grow out of ourselves and into the animated world.

Promiscuous Primes

Is There a Pattern?

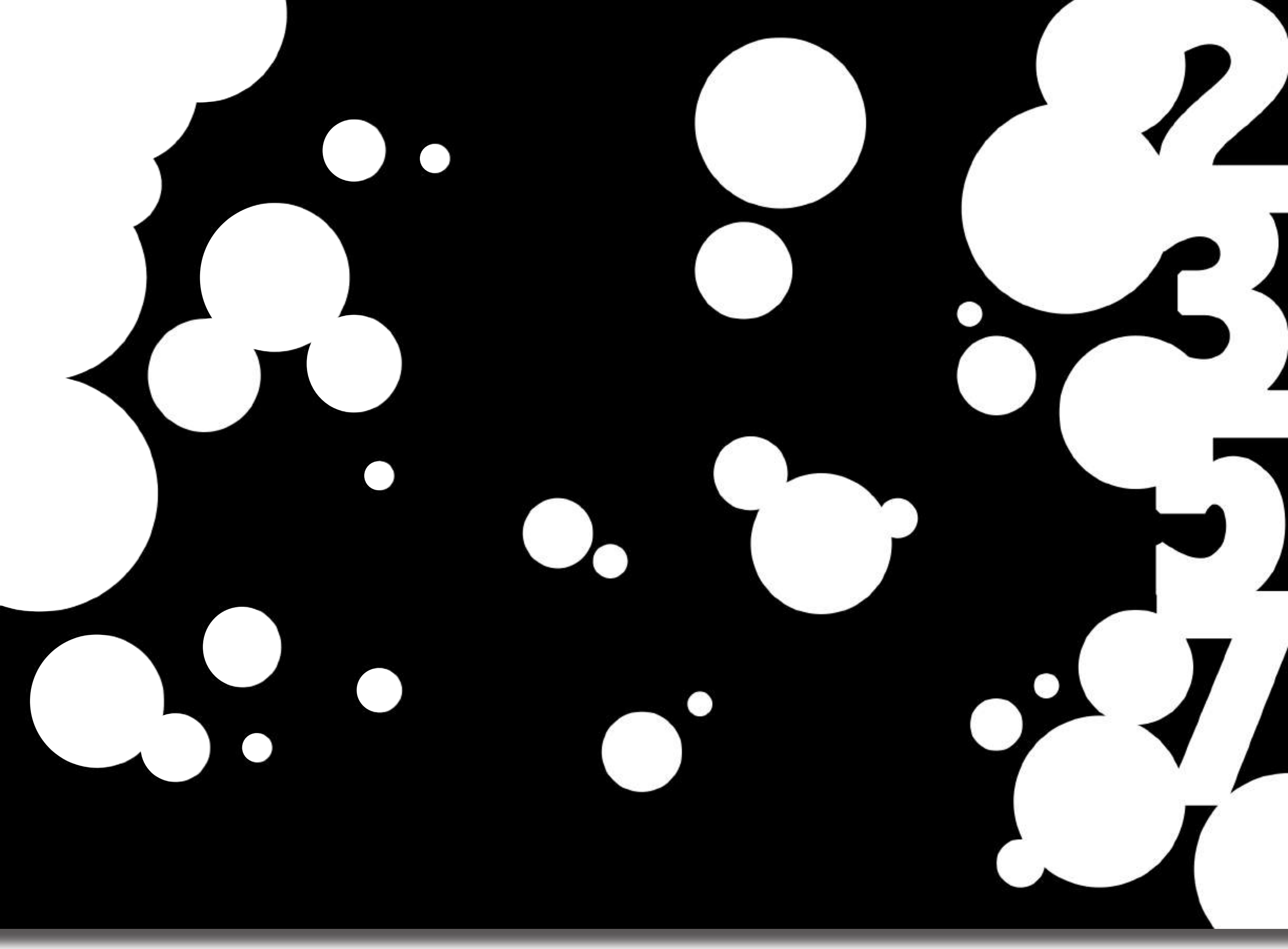
By Oliver Meldrum
Artwork by Jane Sedlak

2, 3, 5, 7, 11, 13, 17, 19, 23, 29… You may recognize this sequence from a distant math class or perhaps this is what you fall asleep every night thinking about.However, regardless of your familiarity with it, this list of numbers is the beginning to one of the most famous sequences in all of mathematics: the prime numbers. The prime numbers are one of the simplest and yet most fascinating objects in all of mathematics. They are defined quite simply as having only themselves and the number 1 as divisors. For example, 7 is prime because there are no numbers other than 1 and 7 that can be multiplied by another integer to get 7. However, 27 is not prime because 27 = 3 x 9. Although this definition is relatively simple, we very quickly run into problems that are very difficult, or perhaps impossible, to answer.

Let's start with one of the most elegant and well known proofs. Euclid's proof from around 400 B.C. stating that there are an infinite number of primes goes like this: Suppose there is a finite number of primes. We can therefore define a collection of all of the prime numbers and this collection has a finite number of elements. Multiply all of the numbers in this collection together and add 1 to achieve a number; call it *n*. Now, there are to possibilities. Firstly, *n* could be prime. In which case, we're done since *n* is a prime that is bigger and therefore different to every other prime in our initial collection of "all" the primes so by repeating the process above, we know that there are an infinite number of primes since we can always find a new one. If *n* is not prime, it must have a prime factor that wasn't in the original collection. This is because every number in the collection divides *n* by definition and no number can divide 2 numbers only one apart from each other. For example, 14 is divisible by 7 but 15 is not. Similarly, 8 is divisible by 2 but 9 is not. This happens because the gap between successive multiples of a number are the size of the number itself so because we're not allowing 1, the gaps between multiples of any number are bigger than or equal to 2. So, we've found another prime number not in the initial collection, again, showing that there has to be an infinite number of primes.

This is one of the many nice results about prime numbers that are relatively easy to understand and prove. However, we very quickly run into unanswerable questions. For example, it is not known if there are an infinite number of twin primes. Twin primes are two primes that are separated by 2. These include (3,5), (11,13), and many more. Again, this seems like a relatively simple question, but despite much work on this question, we still don't know for sure. Recently, Yitang Zhang showed that there are an infinitely-many number of pairs of primes differing by 70 million or less. While 70 million is a very big number, it's exciting to know that that number exists at all!

One aspect of primes that we know, or at least thought we knew, a fair amount about is their distribution and the probability of finding a prime number in a given interval. As the prime number theorem states and shows in detail, it turns out that as numbers get bigger and bigger, it becomes less and less likely that a number will be prime. This makes sense



because for bigger numbers, there are more numbers less than them that could divide the big number.

We have thought for a long time that primes are essentially randomly distributed beyond the obvious patterns. For example, we know that no even numbers are prime and that numbers that end in a 0 or a 5 are not prime. But, beyond patterns similar to these, we don't have a good way of predicting whether a given number will be prime without doing some serious calculations. This seemingly random distribution can be seen through the fact that there are roughly the same number of primes ending with the digits 1, 3, 7, and 9. These are the only digits that a prime can end in since numbers ending in 0, 2, 4, 6 and 8 are even and those ending in 5 are a multiple of 5 and hence not prime.

There are many applications of prime numbers in areas such as cryptography that, to a certain extent, rely on this pseudo-randomization. Despite the lack of predictability, we do know some things about the distribution of primes. For example, we can very accurately predict the probability that a given number will be prime based on how big it is.
Within the last month, an article was published that suggests there may be more patterns to the primes than we previously thought.

On March 11, Robert J. Lemke Oliver and Kannan Soundarajan, two mathematicians at Stanford University, published a paper that has confused many mathematicians and posed many new questions. It uses a lot of very complicated number theory but it has its basis in, and tries to give an explanation for, a relatively simple observation. It can be seen through an example using the very way we write numbers in base 10. If we look at the first million primes, if a prime ends with a 1, then we would expect the next prime to have about a 25% chance of ending in a 1. This would be expected because primes can only end in 1, 3, 7, or 9 and those are equally distributed amongst all the primes. However, what this paper shows, is that the actual probability of the second prime ending in a 1 is much lower than 25%. This also applies to 3, 7, and 9 in the same way that it applies to 1. This finding is very strange as it seems like gaps of multiples of 10 between primes are much less likely than gaps of other sizes. However, the paper shows that this pattern appears in any other numbering system. In other words, the above example uses base 10 but it also applies if you use base 6 or any other base. This seems to suggest that gaps of all sizes between primes are less likely which doesn't make sense. Clearly, there is something strange going on here that we, including the authors of the paper, don't understand.

The prime numbers are one of the most intriguing ideas in mathematics. You can explain them, and questions about them to elementary school students, yet even modern day mathematicians can't answer some of these questions. In addition, almost all of modern day electronic security which relies on public key encryption is based on essentially a lack of understanding about prime numbers. If someone had an efficient way of factoring large non prime numbers that are as long as you want, you could have access to pretty much anything on the World Wide Web.

Manuel Pérez-Quiñones

The Need for Diversity in Computer Science

By Willa Kerkoff

Born in Río Piedras, Puerto Rico, Dr. Manuel Pérez-Quiñones studies human-computer interaction. After earning his DSc from George Washington University in 1996, he worked at the U.S. Naval Research Laboratory and taught at the University of Puerto Rico before coming to Virginia Tech in 2000. Dr. Pérez-Quiñones has authored over 100 academic publications, and is a recipient of the National Science Foundation Career Award. He currently lives in the beautiful Virginia mountains with his wife and two children.

On Tuesday, April 12th, students gathered in King 241 to hear Dr. Pérez-Quiñones, an engaging and accomplished professor of computer science at Virginia Tech, explain why Word processing programs can't spell his name right. He proposes that, not only is diversity in computing a moral imperative, but it is also a clear path toward creating better, more accessible products.

But first of all, Dr. Pérez-Quiñones asks the question "Why is diversity important?". Well, as observed in a study from 1994 by Dr. Martha Maznevski, "For decision making tasks, diversity in membership… is desirable for increasing the number of solutions offered and alternatives considered". Dr. Pérez-Quiñones pushes this further, citing the fact that more diverse juries hand down verdicts more slowly and with greater consideration of the facts. As he puts it, "if I put three people who went to the same high school, lived in the same neighborhood, and studied at the same university the same thing and I put them to make a decision, one of them will say 'yeah that person is guilty' the others will say 'yeah we agree' and then we're done". Another study published in 2006 by Dr. Samuel Sommers agrees, stating that "in many cases, racially diverse groups may be more thorough and competent than homogeneous ones". Social psychology certainly sides with Dr. Pérez-Quiñones, but computing as a field seems to be slow on the uptake.

> "Racially diverse groups may be more thorough and competent than homogeneous ones."

In the last several years, there has been an unprecedented growth in the field of computer science, but the field has not broadened its purview as it expands in number. The number of students taking the AP exam in computer science has greatly increased in the last five years, but there are still several states where no women or students of color took the exam. As Dr. Pérez-Quiñones points out, this problem extends all the way to the faculty and professional level. Students usually take AP exams in order to gain college credit, and faculty members are drawn from the pool of students who finish their degree. When women earn 57% of college degrees but only 18% of all undergraduate degrees in computer and information sciences, it almost stands to reason that there would be so few female professors of computer science.

So we've established the situation, but we do still have to prove that this situation is a problem. Are there any concrete examples of moments where a little more diversity in the development stages might have infinitely improved a technology? The answer is, as Dr. Pérez-Quiñones puts it, "Oh my God yes".

> Women earn 57% of college degrees but only 18% of all undergraduate degrees in computer and information sciences.

One of the classic examples of demographic homogeneity gone awry happened slightly outside of computer science in the field of pharmacology, but the lesson learned there is still very applicable. In order to put a drug on the market, pharmaceutical companies have to undergo rigorous drug development trials, including long-term human subjects testing. However, up until recently, the standard practice was to compose testing groups from only cis men. This resulted in life-threatening errors, as dosages were being prescribed that were far too much or too little for entire groups of people. For example, the FDA recently cut the recommended dose of the sleep aide Ambien in half for women. When taking the traditional dose, women were waking up still under the influence of the drug and attempting to go about their day. The inquiry into dose appropriateness was performed after the FDA received an influx of reports of car and industrial accidents involving female patients. The Ambien case has led to a movement to diversify pharmaceutical testing, although most existing drugs remain unassessed.

Another example Dr. Pérez-Quiñones used was the many problems with facial recognition software. Google faced a case in the summer of 2015 when a black user of Google Photos reported that the app had sorted selfies of himself and his friends, also black, into a folder labeled "gorillas". The error was immediately addressed, with Google engineers corresponding with the customer on Twitter as they worked to solve the problem. Another similar case was presented in 2009 when a Youtube video was uploaded showing that the face tracking feature of HP computers does not recognize black faces. A black man and his white female coworker were using an HP desktop computer when they realized that the webcam was moving and shifting focus in response to her face, it was not doing the same when his was in frame. Both of these situations are mind-boggling, especially considering the amount of money and time invested in research and development by these companies. HP spends $2.57 billion dollars on R&D annually, and Google's R&D budget is a whopping $8 billion. Somehow, in the midst of all that development, there was no thought that the technology should be tested on faces of several races. Furthermore, as Dr. Pérez-Quiñones pointed out, this draws further attention to the problem of homogeneity in the workplace. If there had been greater workplace diversity in the R&D departments at HP or Google, these errors might have been caught earlier on. As is, two of the biggest tech companies in the world spent additional resources addressing the very public embarrassment of having made such a fundamental and offensive error.

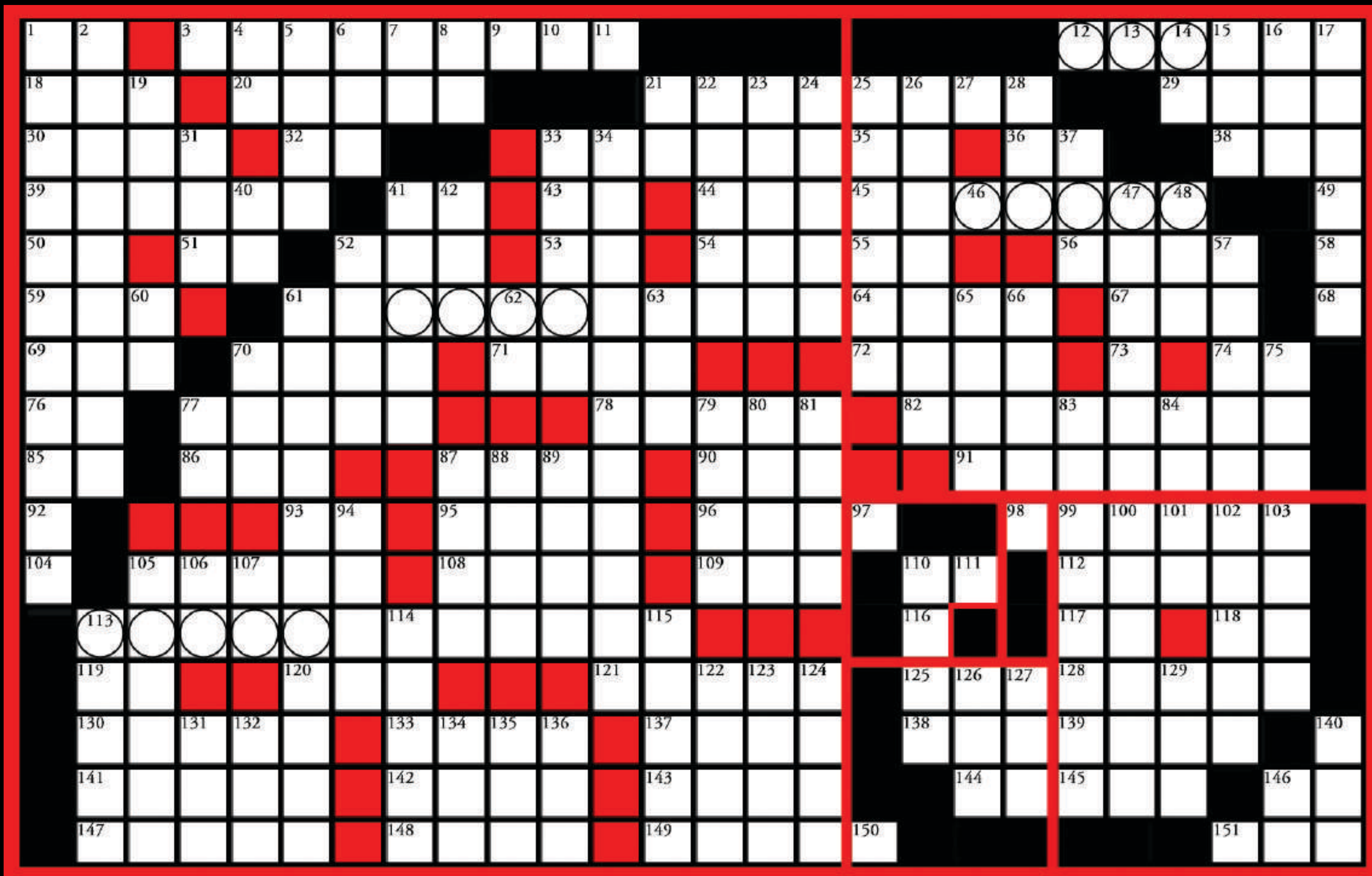
> The face tracking feature of HP computers does not recognize black faces . . . If there had been greater workplace diversity in the R&D departments at HP or Google, these errors might have been caught earlier on.

As Dr. Pérez-Quiñones continued with his talk, it became clear that he had a truly depressing plethora of examples. Trans or non-binary individuals are harassed by TSA officials because the screening interface requires operators to select "male" or "female" in order to approve security checks. Website designs are unfriendly to users who take fewer risks, a behavioral profile usually associated with non-cis male individuals. The American version of a Google search brings up fewer political results if the interface is set to a language other than English. Credit card companies require a person's mother's maiden name to be shared as a security question, when many people (including Dr. Pérez-Quiñones) have their mother's maiden name as part of their own given name. This significantly increases the risk of identity theft in those populations. The far-reaching effects of homogeneity in computing multiply the more you look, and the potential risks to already disadvantaged populations are truly devastating.

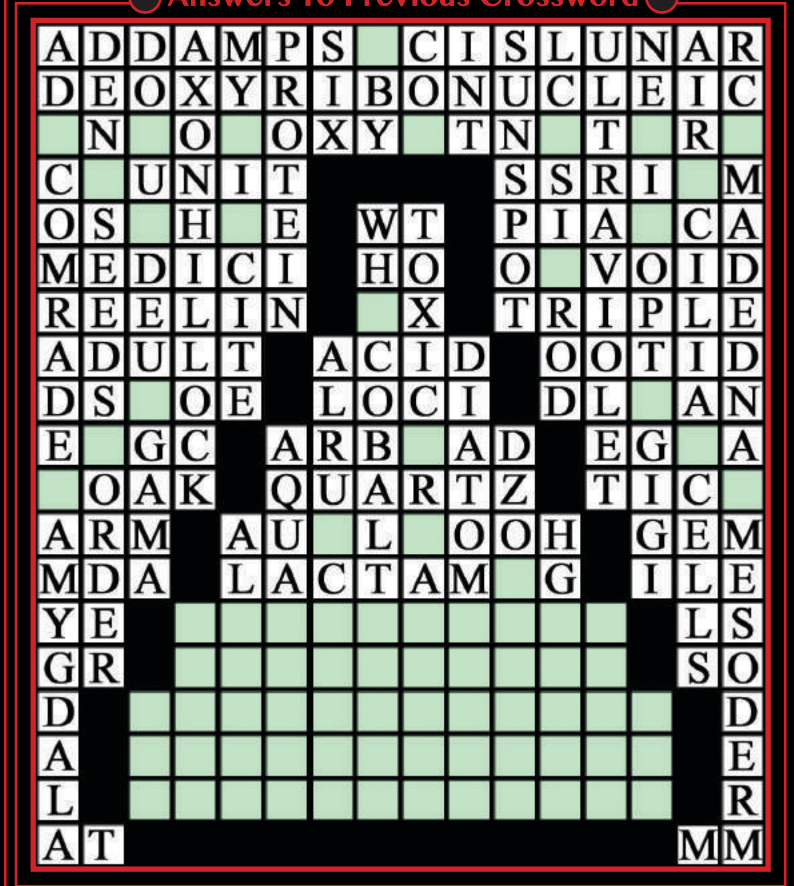
So what, then, can be done? Dr. Pérez-Quiñones was the first to admit that he does not have the answer. Accessibility is a problem that we have not solved as a society, and the challenges are too great to be tackled by just one academic. Ultimately, it will partially be the job of this generation of computer programmers to open up their chosen field. And while some people might feel that such work would be a selfless act, Dr. Pérez-Quiñones made it clear that this is not true. In every case, regardless of the circumstance, a more inclusive view benefits everyone. And as computer science continues to expand as a booming new scientific field, it is more important than ever that the people already at this party make it clear that everyone is invited.

> The effects of homogeneity in computing multiply the more you look, and the potential risks to already disadvantaged populations are truly devastating.

> "Computer science students and professionals should care deeply about this inequity: a lack of diversity in software development teams can have serious consequences for a fair society."
>
> - Manuel Pérez-Quiñones



Answers To Previous Crossword



Acknowledgements

A Lexicon For the Anthropocene
Photographs courtesy of http://curious-places.blogspot.com/2013/02/the-blur-building-yverdon-les-bains.html

Interview with Manuel Pérez-Quiñones
Photograph courtesy of http://cci.uncc.edu/directory/perez-quinones-manuel

Corrections

In V4I3, the cover art was misattributed to Claire Kotarski. The cover art was in fact the work of Zimeng Xiang, an exceptional artist who deserves recognition for exquisite work.

Crossword Corner

"Science Is Golden"

By Rachel Dan

ACROSS

1 Pass this Monopoly corner to collect $200
3 What the four circled words have in common
12 Unit of depth equalling 6ft
18 Eggs, to Caesar
20 The left brain controls the ___ half of the body
21 Phenylbutazone, informally
25 Title for an emperor of Russia
29 99-ACROSS, underground
30 Shakespearean king
32 With 1-ACROSS, a request to continue
33 Madhouse
35 Name of ionization energy equation, first two letters
36 Prefix meaning "against"
38 Playground game
39 Komodo or Puff the Magic
41 Activation energy, abbrev
43 The Empire State
44 This interferometer measured cosmic microwave background radiation from 1999-2008
45 To make uneasy
49 Quantum number indicating electron energy level
50 Symbol of element named after 13-DOWN
51 Element that sounds like an internet browser, abbrev
52 Often paired with feathering
53 Type of online chat
54 Devour
55 Starts and ends the solfege scale
56 One of a series of bars forming traintracks or bordering a staircase
58 It makes a man mean
59 To sleep briefly
61 Rome, Assyria, and Babylon
64 Bearded antelopes
67 Flower wreath worn around the neck
68 Often used to symbolize time
69 Barbecue treat, or a curved bone attached to the sternum
70 Wood heap to cremate a corpse
71 Presidential power
72 Brontë protagonist Jane
73 Symbol: chemical equilibrium
74 A note to follow Sol
76 Pacino of "The Godfather"
77 Untamed, as a cat
78 Inner opposite
82 Our galaxy
85 *Waste Land* poet _ _ Elliot
86 Type of brain scan
87 One who has graduated
90 Poisonous plant
91 Members of the clergy
92 First initial of physicist Newton
93 Myself and I
95 Famous astronomer Sagan
96 As opposed to max
97 The first consonant not to be an atomic symbol in the Periodic Table
98 Symbol for potential energy
99 29-ACROSS, aboveground
104 Universal blood donor
105 Protein facilitating muscle contraction
108 Latin palindrome meaning "to be"
109 Precedes "quence" or "cution"
110 *The Synapse* Chief Layout Editor, initials
112 French farewell
113 Hemophilia
116 Arrhenius's pre-exponential factor
117 Ancient Egyptian sun god
118 With "E", a first responder
119 Expression of agreement
120 Charged particle
121 Oberlin neuroscience professor
125 Canine companion
128 Dome-shaped icy dwelling
130 A smoothy, silky fabric
133 Times New Roman or Helvetica
137 Environmentalist and former opponent of George Bush
138 Purchase at a pub
139 Trims off: "___ in the bud"
140 Atom satellite, first letter
141 Female name, or pizza topping
142 Mythological wife of the titan Cronus
143 Alternatively, pigs
144 To finish
145 The Hadean was earth's first one
146 Domestic bovine
147 "Dressed up to the ___"
148 Cedric Diggory's father
149 Horse's pace slightly faster than walking
150 Quantum number indicating electron subshell
151 Number of Martian moons

DOWN

1 The design of this crossword
2 Projects beyond a lower point
3 _. elegans
4 Sound often heard in the search for a hard to find word
5 Dorothy's cowardly companion
6 Visual relay in the thalamus, abbrev
7 Element named for the Norse god of thunder, abbrev.
8 Inquiry, via text
9 Electron subshell when L = 1
10 Energy of a photon: _ = hν
11 Symbol for entropy
12 Counterpart of Celsius
13 First initial of physicist Einstein
14 Symbol for Thallium
15 It's over your head!
16 Female reproductive cell
17 Chick or electro
19 Type of battery
21 With "-pass", a form of heart surgery
22 Skin sore
23 Uncommon plural of 'tuba'
24 An Electron ___ light when falling
25 Walk heavily
26 Antonym antonym
27 Excellent mark
28 Court Case: ___ v Wade
31 Receives visual input from bipolar cells, abbrev
33 Japanese animation
34 Sick, but not showing the signs
37 Sound made when cold
40 Boolean operator with a value of 1 or 0
41 Painter's stand
42 Public hangings
46 Element comprising 78% of earth's atmosphere
47 Wagner had a "ride" writing an opera on these women
48 ". . . had a farm, ___-I-O"
52 She authored Anthropocene in this Issue of the *The Synapse*
57 Flower giving its name to a shade of purple
60 *The Synapse* Art Coordinator, initials
61 Not purines
62 Unit of energy involving electron acceleration
63 Written promise to pay
65 Acid produced during the breakdown of purines
66 Vend
70 Miles ___ hour
75 Affirmative votes
77 Type of radio
79 Fourth dimension, or what prisoners do
80 Wickedness
81 Oberlin chemistry professor
83 Energy of motion, abbrev
84 The Dairy State, abbrev
87 Depending on the game, these cards can be low or high
88 To cut with a laser
89 Celestial she-bear
94 With "-thermic," a reaction that absorbs energy
97 Electron subshell when L = 2
98 Enthalpy: H = E + P_
99 Military branch trained for land and sea
100 Music, in slow tempo
101 Joe action figure
102 Notifications, as in business
103 Prefix meaning "oneself"
105 First column of the Periodic Table
106 Main magnetic element, abbrev
107 ___ and fro
110 Every dorm has at least one.
111 Symbol for density
113 The God Particle: 'Higgs ___'
114 With "-red", a type of non-visible light
115 Number of planets in our solar system
122 Wetland, or to anchor
123 Latin word meaning "therefore"
124 Home of a fledgling bird
125 Public prosecutor
126 Prehistoric
127 The science of rocks, abbrev
129 Hospital assistant, abbrev
131 Element abbreviated Sn
132 Common contraction
134 Georg's unit of resistance
135 The Matrix protagonist
136 Graduate students who help teach class, abbrev
140 With "-thermic," a reaction that releases energy
146 Sound of pain
150 Dopamine precursor: _-DOPA
151 $\Delta G = \Delta H - \_\Delta S$

/syn . apse/ noun : the point at which a nervous impulse passes from one neuron to another

The Synapse is an undergraduate science magazine that serves as a relay point for science-related information with a threefold objective. First, we aim to stimulate interest in the sciences by exposing students to its global relevance and contributions. Second, we work to bridge the gap between the scientific and artistic disciplines by offering students a medium through which to share their passions, creativity, and ideas. Third, we strive to facilitate collaboration between undergraduate institutions across the country and especially within their natural science departments.