

SciTECH

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table of contents

Claire Fu '22

4. Warmer Climate, Denser Ice

Henrik Torres '22

6. Hydrogels: A Miracle Cure for Heart Attacks?

Praj Chirathivat '22

8. Your Package Has Been Delivered—By A Drone

Sophie Vulpe '22

10. In Space, No One Can Hear You Scream

Max O'Connor '21

12. Dr. Selena Gell: From Scientific Research to Teaching

Claire Yuan '21

*14 Q&A w/ Mr. John Ford: Being A
Well-Rounded Scientist*

Kenadi Waymire '22

*15. When Natural and Programming Languages Meet: Machine
Learning Aids the Decipherment of Lost Ancient Languages*

Joy An '23

*16. Life, the Universe, and Sum of Cubes:
Finally an Answer for 42*

Ryan Kim '23

*18. Apple September Event: The New iPhone,
Apple Arcade, and More*

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Warmer Climate, Denser Ice

By Claire Fu '22

With youth-led strikes all over the world demanding change and the UN 25th International Climate Conference coming up in Chile, climate change is becoming an increasingly relevant issue today. New studies come out every year on the topic, one bleak discovery after another appearing on various news outlets. The newest information: the Greenland ice sheet is getting denser.

When a heat wave struck Greenland this year, over half of the Greenlandic ice sheet—the second largest after the Antarctic ice sheet—started melting at an unprecedented pace for the first time since 2012. A study published by *Nature* stated that along with the sudden increase in melting ice, amplified by the warming climate, the ice sheet is becoming denser as well.

Many people believe Greenland is a thick wall of impenetrable ice. In reality, about 80 percent of the ice is fresh snow layered on top of thicker, older snow, called firn, which in turn is compressed into glacial ice over time. As firn contains many air pockets, liquid water melting from the surface normally gets trapped inside. Through a complex “plumbing” system, firn then absorbs the water like a sponge. In 2014, data from a radio-echo sound (a kind of ultrasound machine for ice) showed that some ice is stored within the crevices of the system until the arrival of winter, when they are either released back into the system or refrozen.

In the summer of 2012, a group of researchers noticed that the Greenlandic ice was behaving differently. They found fully

Graphic from National Geographic



The Greenlandic Ice Sheet



A segment of a firn core, essentially a baby ice slab that eventually will grow to be meters thick.

compact, solid slabs of ice right beneath the freshly fallen snow. The lack of air pockets prevented runoff water from entering the ice sheet; instead, it transferred straight into the ocean. Every summer of increased melting led to a thicker and harder slab of ice spreading inland to higher and colder grounds.

Researchers estimate that ice slab proliferation has the potential to add three inches to sea levels by 2100, a third of all the current contributions to sea level rise.

Due to global warming, the ice is melting at an unprecedented rate. Glaciers are losing one billion tons of ice per day, and the runoff has expanded by 26 percent. Researchers estimate that

ice slab proliferation has the potential to add three inches to sea levels by 2100, a third of all the current contributions to sea level rise. In addition, glaciologists pointed out that the slabs of ice are not nearly as reflective as firn. The ice absorbs more solar radiation than firn and warms up, resulting in the formation of even more slabs, a vicious cycle that sets off a slew of environmental issues. Some runoff might not even flow into the ocean. They might end up at the very bottom of the sheet, assisting as a slippery slide and lubricating the area where ice comes in contact with water, leading the sheet to flow towards the ocean with more ease than ever.

The greatest contribution of this study, however, is a deeper understanding of Greenlandic ice patterns. With this information, scientists are now able to predict with higher accuracy the predictions of future sea level rise and assist threatened coastal communities. Scientists have also gained an increased awareness that the more carbon that is being emitted into the atmosphere, the more likely the Earth's northern ice sheet would be unpredictably transformed in an insidious manner.

HYDROGELS: THE MIRACLE CURE FOR HEART ATTACKS?

By Henrik Torres '22

Every 40 seconds, someone in the US experiences a heart attack, amounting to an average of 790,000 cases every year. A heart attack occurs when there is reduced blood flow to a section of the heart, resulting in damaged tissue or dead cells. One out of every five heart attacks shows no other symptoms, but damage is still done to the muscle. Following a heart attack, the heart muscles are weakened, resulting in thinner chamber walls and a frail heart. With cardiovascular disease on the rise—nearly half of adults in the U.S. are afflicted—researchers are coming up with a new treatment plan: using hydrogels to repair the heart following a heart attack.

There was previously no cure to repair the damage done after a heart attack as scar tissue forms around the heart and diminishes the efficacy of the muscles, leading to heart failure. Now, a company called Ventrix, based at the University of California, San Diego, has successfully conducted the first successful human trial of using an injectable hydrogel to repair the damage,

stimulate muscle regeneration, and restore cardiac function.

VentriGel, the hydrogel compound injected into the heart, works as a scaffold that facilitates a curative environment for healthy cells to repopulate. The hydrogel substance is made from cardiac connective tissue from pigs. It is then stripped of the heart muscle cells the human body would reject and run through an extensive cleansing process. Afterward, it is freeze-dried and converted to a powder form to be liquified into an injectable, semi-solid and porous fluid for the minimally invasive procedure.

The main goal of the Phase 1 trial was to evaluate the safety and feasibility of VentriGel in 7 patients who suffered from a heart attack within the past year and 8 who suffered a heart attack three or more years ago. Following the injection into the damaged regions of the heart and patient tracking for six months after the treatment, the Ventrix team reported that the hydrogel was effective and showed no



Skeletal muscle tissue of pigs is processed to yield VentriGel.

adverse effects. In fact, VentriGel nearly restored the damaged heart chamber walls to their original condition before the heart attack. The trial completed its goal to measure the effects of the hydrogel and whether it improves cardiac function of the patients.

VentriGel nearly restored the damaged heart chamber walls to their original condition before the heart attack.

Following the success of Phase 1, Ventrix is preparing for the Phase 2 clinical trial consisting of a larger, randomized trial. While this FDA approved Phase 1 clinical trial is

monumental progress, there is still much work to be done in this field of research. In the coming years, hydrogel treatment may be able to reduce deaths due to heart failure caused by the weakening of heart muscles after a heart attack.

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Your Package Has Been Delivered— By A Drone

By Praj Chirathivat '22



Artist's depiction of a delivery drone

Graphic from Getty Images

As the demand for faster deliveries rises, many retail corporations in the US are working to implement new and innovative methods to transport their products to their customers. Adding automation and artificial intelligence are ways a company can not only manufacture and deliver the items faster but also reduce the cost of manual labor. Thus, many major retailers are moving towards implementing drone delivery services.

The biggest e-commerce retailer in the world, Amazon, is about to implement all-electric autonomous drones into their delivery process. Announced at their inaugural re:Mars Conference in 2019, an event discussing the latest innovations in robotics and machine learning, Amazon's recent delivery drones can fly up to fifteen miles and deliver packages to customers in less than thirty minutes. The drones use various sensors

and algorithms to detect objects impeding their path and the surrounding environment. "We know customers will only feel comfortable receiving drone deliveries if they know the system is incredibly safe," said Jeff Wilke, the CEO of

Amazon plans to make half of all their deliveries carbon-free.

In addition to Amazon, Walgreens and FedEx are also launching their own automated drone programs. Executing "final-mile deliveries, improving access to health

Amazon's recent delivery drones can fly up to fifteen miles and deliver packages to customers in less than thirty minutes.

Amazon's worldwide consumer division. "So, we're building a drone that isn't just safe, but independently safe, using the latest artificial intelligence technologies." Amazon's delivery drones also have a positive impact on the environment. Lowering carbon emission and the use of fossil oils, drones run totally on electric power and are a more sustainable alternative to the conventional trucks used to carry products. By 2030, Am-

azon plans to make half of all their deliveries carbon-free. care products, and creating possible new growth for local businesses" are the companies' objectives in this project. Partnering with Wing Aviation, a subsidiary of Google, Walgreens would possibly be the first US retailer to provide on-demand commercial drone delivery. By using drones, the company said it will make over-the-counter medicines, food, and other products available to nearby residents within minutes

after their order. Walgreens already has 9,700 stores nationwide, and, therefore, would be able to capitalize on the drone delivery services. Walgreens is currently testing its drone delivery service in Christiansburg, VA because of Wing's connections with the Virginia Tech Mid-Atlantic Aviation Partnership, a test site for unmanned aircraft. Final-mile delivery is the biggest component of the overall cost for companies and utilizing drones instead of people will lower their expenses.

Despite the advantages drones give to companies, there are still some issues that need addressing. The biggest concern the public have involves the invasion of privacy. Many companies install cameras into their drones to make sure the product is successfully delivered and to avoid trees and other obstacles in the way. However, the camera may accidentally take a video of people and properties who aren't associated with the transaction. Therefore, drone regulations need to be updated in the future if they will be used as a staple mode of transporting goods for retail companies. However, despite these is-

suess, drone delivery services are the next step in engineering and transportation. The efficiency and convenience of drone delivery will create a huge impact on people's lives in the near future.

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Artist's depiction of a delivery drone

Graphic from Adobe Stock

In Space, No One Can Hear You Scream

"Ringing" Black Holes and What They Mean for Einstein's Theory

By Sophie Vulpe '22

Graphic from Max Isi/NASA

Nearly four years after the monumental observation of gravitational waves, scientists have detected tones in the "ringing" of a black hole for the first time, corroborating yet another one of Einstein's theoretical predictions. According to Einstein's theory of general relativity, a black hole formed from the collision of two other black holes produces "ringing" gravitational waves. However, what is special about the ringing of these gravitational waves is that they encode specific information about the nature of the black hole, namely their mass, spin, and electric charge.

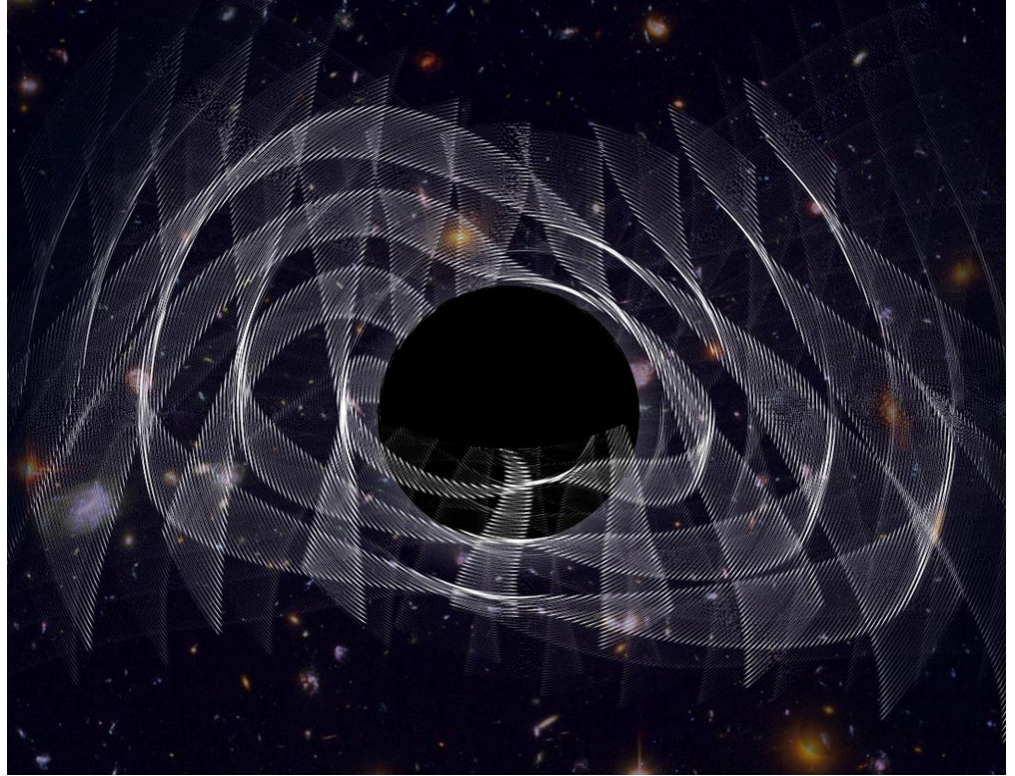


Illustration depicts a black hole ringing as it merges from two smaller black holes. The collision also produces the gravitational waves (in white).

On September 14, 2015, scientists first detected gravitational waves using LIGO, the Laser Interferometer Gravitational-wave Observatory. Gravitational waves are waves that transport energy in the form of gravitational radiation and propagate through a gravitational field, creating a ripple-like effect in space in the process. In order to study gravitational waves, scientists have translated the signals into sound waves, which crescendo over time. When black holes merge, the gravitational waves translate into a "chirping" sound. The chirp is loudest at the moment when the black holes fuse. The infant black hole that is created from the collision of the two parent black holes also produces gravitational waves that "ring;" however, physicists previously assumed that the noise created by the infant would be too faint to interpret amid the loud noise from the initial collision of the parents. Therefore, traces of this ringing have to be studied sometime after the peak, when the signal becomes too faint to be of much significance.

The team that published the findings, led by Maximiliano Isi of MIT's Kavli Institute for Astrophysics and Space Research, found a way to extract a black hole's reverberation from instants after the signal's peak. In previous work led by Isi's co-author, Matthew Giesler of Caltech, the same team showed that the signal, particularly the portion immediately after the peak, contained "overtones," which are loud, short-lived tones.

"We detect an overall gravitational wave signal that's made up of different frequencies, which fade away at different rates, like the different pitches that make up a sound," Isi said. "Each frequency or tone corresponds to a vibrational frequency of the new black hole."

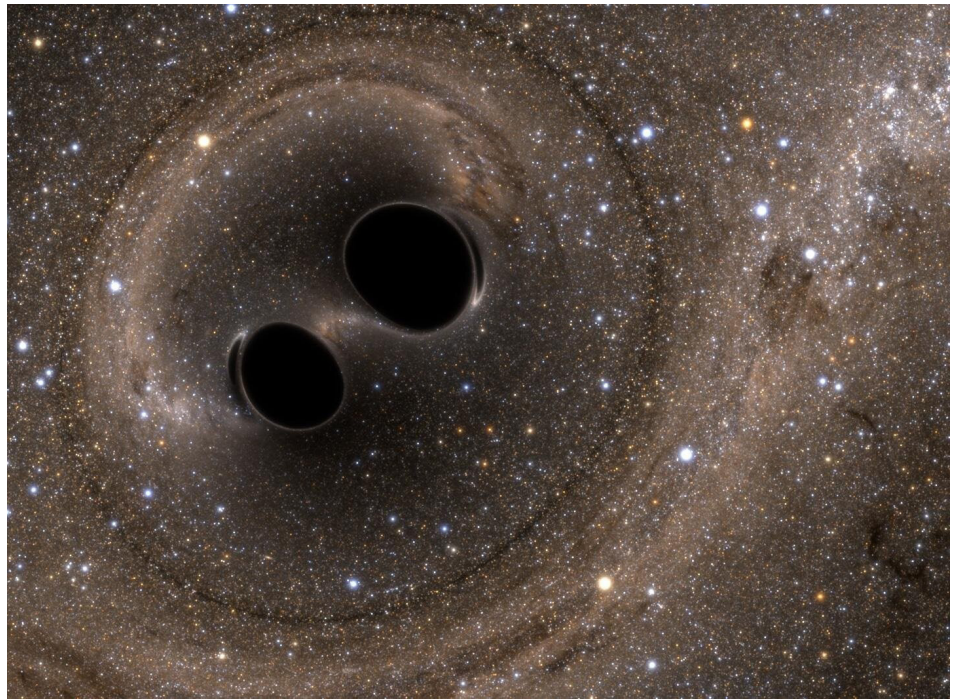
When the team took the overtones into account, they were able to identify a ringing pattern specific to a newly-formed black hole.

“This was a very surprising result. The conventional wisdom was that by the time the remnant black hole had settled down so that any tones could be detected, the overtones would have decayed away almost completely,” noted Saul Teukolsky, the Robinson Professor of Theoretical Astrophysics at Caltech and adviser to Giesler.

Using these ringing patterns, physicists were able to use the equations Einstein outlined in his theory of general relativity to calculate the mass and spin of the black hole. These measurements concurred with previous measurements. If they had not matched, then the ringing patterns would have encoded more information than the mass, spin, and electrical charge of the black hole. However, the extra information would have violated Einstein’s No-Hair Theorem, stating that the only characteristics needed to define a black hole are mass, spin, and electrical charge, without any “excess hairs.” The alignment of these measurements with Einstein’s theory is significant as it paves the way for more advanced work in ringing patterns in the future with better equipment.

As LIGO improves its resolution techniques and more sensitive instruments are developed, scientists will be able to use the ideas put forth by Giesler and the Isi team to “hear” the ringing of other newborn black holes.

“In the future, we’ll have better detectors on Earth and in space, and we will be able to see not just two, but tens of



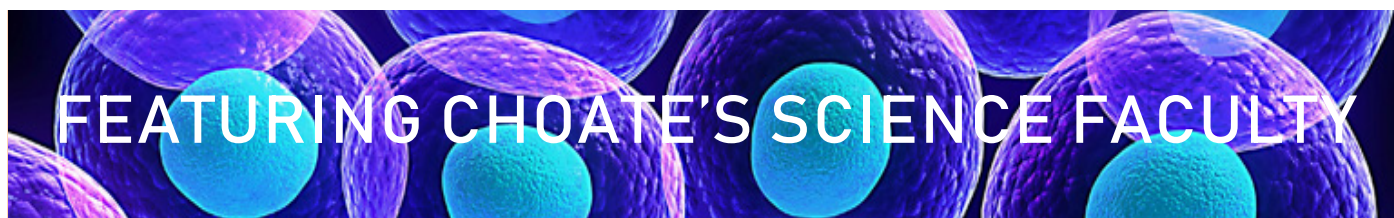
This simulation shows how a black hole merger would appear to our eyes if we could somehow travel in a spaceship for a closer look. It was created by solving equations from Albert Einstein’s general theory of relativity using LIGO data from the event called GW150914.

modes, and pin down their properties precisely,” Isi remarked. “If these are not black holes as Einstein predicts, if they are more exotic objects like wormholes or boson stars, they may not ring in the same way, and we’ll have a chance of seeing them.”

Clearly, the future of ringing patterns is abuzz with potential.

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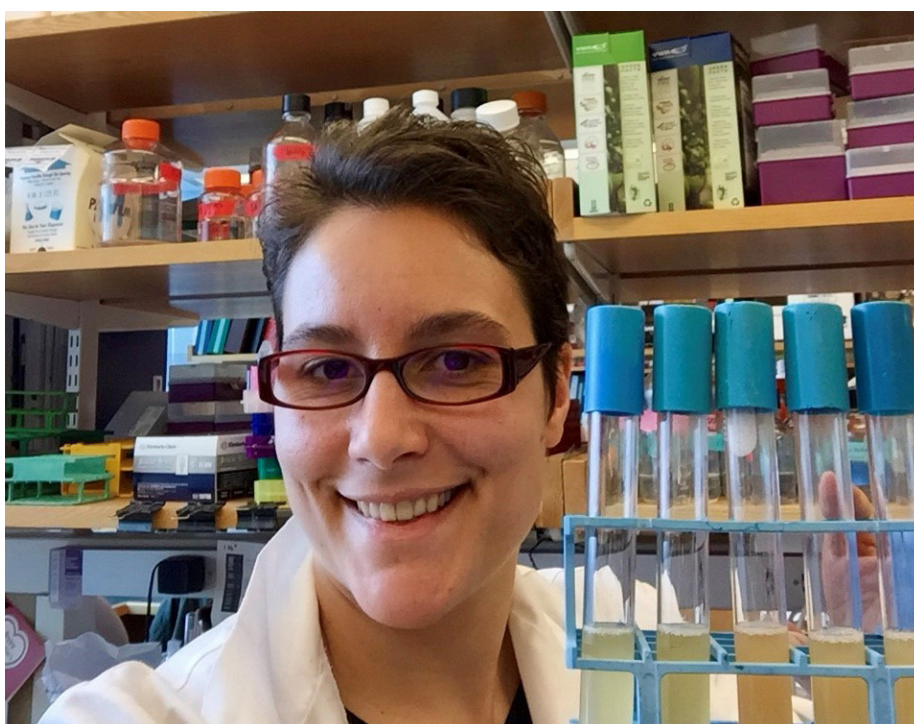
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Dr. Selena Gell: From Scientific Research to Teaching

By Max O'Connor '21

Photo courtesy of Dr. Selena Gell



During her time at Choate, Dr. Gell has taught Honors Biology and Cell and Molecular Biology. Dr. Gell has an extremely strong research background with five years of work as a PhD student and five more as a postdoctoral researcher. This knowledge and experience allows her to teach a variety of classes and successfully train Choate students in true scientific research while leading the biology section of Choate's Science Research Program.

Dr. Gell was captivated by the scientific world from a young age. As a child, Dr. Gell was surrounded by family friends who were scientists and lead lives full of interesting people, ceaseless learning, and careers that improved the world through scientific advancement. On top of this, Dr. Gell possessed an innate interest in the natural world, often catching frogs and insects while spending most of her time outdoors. By the time she entered high school, she knew she wanted to become a scientist and eagerly took all of the science classes that were available to her. Beyond taking the normal sciences in high school, Dr. Gell also participated in an internship at an animal forensic laboratory.

For college, Dr. Gell attended Brandeis University where she considered majoring in either chemistry or biology. Eventually, Dr. Gell's interest in the work of some of her biology professors led her to choose biology and work in the Fulton Lab at Brandeis. While working in the lab, Dr. Gell studied a form of programmed cell death known as apoptosis, which has applications in developmental processes and cancer. This initial exposure to scientific research strengthened Dr. Gell's goal to pursue a PhD in science. However, Dr. Gell knew that she wanted to take a break from her traditional education for a couple of years in order to participate in something new that benefited the world.

After graduation, Dr. Gell worked with Teach for America for two years while teaching chemistry, biology, and physical science at a low-income high school in Phoenix, Arizona. Although this wasn't the experience that initially revealed a passion for teaching within Dr. Gell, it most definitely helped shape the idea of incorporating more teaching in her future career. To combine her interests in both teaching and research, Dr. Gell decided to pursue a PhD at Brown with the goal of working at a small liberal arts college with a lab of her own in the future. For her PhD in molecular and cell biology, Dr. Gell studied selfish genetic elements using fruit flies in the Rob Reenan lab.

Once finished with her formal education, Dr. Gell became a post-doctoral research fellow at Harvard Medical school. During her time at Harvard, Dr. Gell studied protein complexes involved in gene regulation, using the same yeast found in beer and bread. After five years of dedicated research work at Harvard Medical School, Dr. Gell stumbled across a job opportunity at Choate. Dr. Gell felt that the career opportunity offered by Choate would allow her to return to the teaching aspect she loved about science.

One life lesson that Dr. Gell learned from her experience as a scientific researcher is persistence: "In science, most of the things you do fail. You try to experiment, it doesn't work the first five times you do it, it doesn't work the first ten times you do it. Every time you do it slightly differently, chang-

ing a variable until suddenly, one day, you actually get a result." She also notes the importance of time management as a key component to a successful life and career, "being in science taught me a lot about balance in my life and having to make time for things that are important to me outside of work. Being a researcher is the kind of job that can expand to fill all available time and I had to learn how to set aside time for me so that I came back to my work excited, refreshed, and ready to take on challenges."

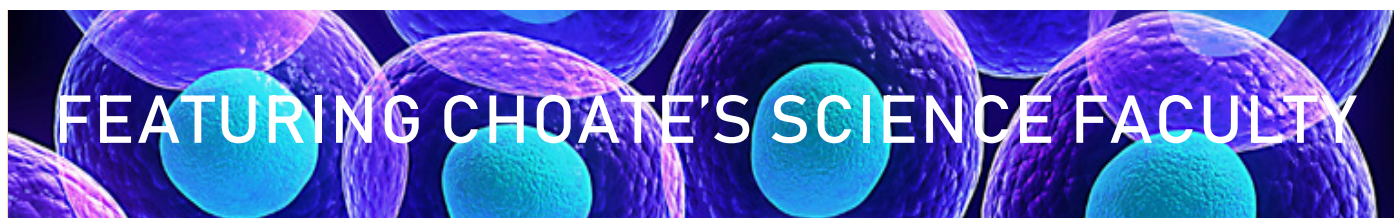
One of the things Dr. Gell set aside time for apart from her work life, was competitive rugby. In fact, Dr. Gell played competitive rugby for twelve years after starting in college at Brandeis. She also played for The Lady Blues while living in Arizona and Providence women's rugby while at Brown, before retiring in 2012. Ultimately, competitive rugby provided Dr. Gell with an extremely useful outlet to refresh her mind from the demanding workload of college and laboratory research.

With such an impressive background in both the academic and the athletic world, Dr. Gell serves as a perfect example of why being a Choate student is such an invaluable opportunity and experience. Faculty members like Dr. Gell allows us to not only receive an amazing education, but also learn important life lessons from their experiences. Together, this knowledge and wisdom are truly the reasons why so many Choate alumni have regarded their time here as priceless.

Photos courtesy of Dr. Selena Gell



Dr. Gell playing competitive rugby as a graduate student at Brown.



Q&A with Mr. John Ford: Becoming A Well-Rounded Scientist

By Claire Yuan '21

This year at Convocation, Mr. John Ford, a long-time Choate science teacher, received a faculty chair for his incredible dedication and passion for teaching. Recently, I had a chance to sit down with Mr. Ford to talk about his background in STEM and teaching, as well as some fun facts and advice for students.

Q: What is your background in STEM?

A: I was a biology major in college, and I also did some graduate work in similar fields and got a master's degree. In my 45 years of teaching or so, I've taught all levels of biology and introductory physics—that is, first year physics—and first year chemistry.

Q: What made you decide to pursue a career in STEM?

A: I think I found, when I was in high school, that both my strength and interest was more in [STEM] areas—particularly, my interest was in biology. In high school, I never really took to the more verbal courses: English and history. I mean, I worked hard in them, but they didn't come easily to me, and it felt like STEM came more easily. And when I went off to college, I was pretty certain that I was going to major in biology—and I did. Sometimes people change their minds, but I didn't. I did find some areas of biology that I didn't know I would be interested in until I was exposed to them in college, so that was good. I got to do a little bit of research with a couple of professors, and so I continued to pursue it.

Q: What are your views on STEM education at Choate and beyond?

A: I worry a little bit about over-specialization. I think that sometimes high school students are too quick to specialize in an area and therefore dispense with other areas that they don't realize they might have an interest in and are kind of leaving behind. So I'm more of a fan of a general education, or what we consider a liberal arts education. I think that it's really important—no matter what you're doing—to be reasonably experienced in reading, writing, and scientific thinking, as well as quanti-

tative skills. I don't think any high school student should be avoiding any of that.

Q: What are some important things you think Choate's future scientists should know?

A: I think that what they should be careful of is getting too far down the road with something supposedly advanced in study without having a really good coverage of fundamentals. I worry sometimes when I see what students are doing in SRP in that they are looking at some pretty intricate and detailed studies related to their summer work in the lab, and that's at the expense of covering the fundamentals. So what I think Choate science students should know is that it's okay to take your time. Make sure that you don't rush ahead into detailed, advanced work without covering core concepts first.

Q: What is your favorite book and/or character?

A: I guess still my favorite book is *The Catcher in the Rye* and my favorite character is Holden Caulfield. It's hard to pick one favorite, but I feel like Holden Caulfield has been with me for a long time.

Q: What is your proudest STEM or education accomplishment?

A: In my earlier days, my primary area of interest was in marine biology, and I think I did quite a few things to establish the study of marine science here at Choate. It's been a long time since I've taught it here, but I think I laid a lot of groundwork for that. I did some pretty good and fun research myself, especially in coastal marine ecosystems and some coral reef ecosystems, so I guess that's my biggest accomplishment.

When Natural and Programming Languages Meet: Machine Learning Aids the Decipherment of Lost Ancient Languages

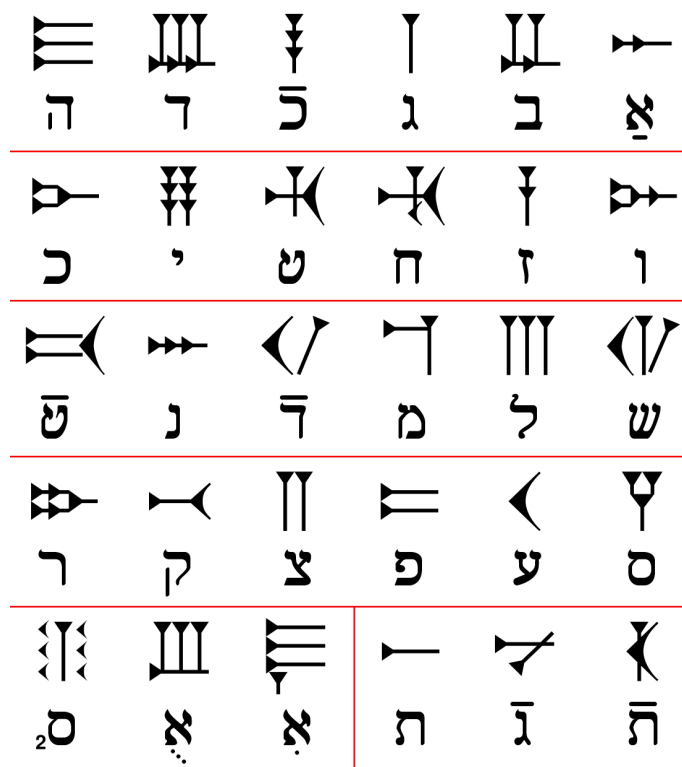
By Kenadi Waymire '22

For years, many lost languages have stayed exactly as they sound—lost. Some languages have been deciphered by hand, matching these texts to other languages and picking out similarities. However, new technologies have been introduced to make deciphering these languages simpler and more widespread; teams across the world have been using machine learning and neural networks to automate the code breaking of ancient languages. So, even though many languages are still unable to be understood, this automation can be used to explore histories and reinvent cultures like never done before.

A team of researchers from MIT Computer Science and Artificial Intelligence Laboratory, Regina Barzilay, Benjamin Snyder, and Kevin Knight, created a statistical model run by computers to work on breaking these ancient texts. They used a model based on the traditional techniques (the assumption that each word is made up of morphemes that can be correlated to use in other languages) and incorporated human-like intuition into the machines to generate results. Using complex equations, algorithms, and basic probability, this team has been able to discover the meaning to one-third of Ugaritic, an ancient Semitic language similar to Hebrew in writing system yet wildly different in word structure and vocabulary—not a perfect result, but more accurate and efficient than a human team with no machine help.

Barzilay and Jiaming Luo from MIT teamed up with Yuan Cao from Google's AI lab to work on using new technologies to decipher lost lexicons. They fed a program huge amounts of text from the language to determine which words appeared together frequently. Again, using mathematical reasoning and presenting these words as simple vectors, the algorithm was able to compare these patterns to similarly structured languages to piece together a previously unknown language. While these programs aren't perfect—they need data from known similar languages to function, and they will need a considerable amount of time

Graphic from Wikipedia



Ugaritic vs. Hebrew Alphabets

until they can be applied in everyday language investigation, they are still great innovations as they eliminate the chance of human errors.

If you have ever been interested in reading a language not previously decrypted, you may not have to wait for much longer. Due to work from people such as Regina Barzilay and her team, machine learning, neural networks, and mathematical reasoning are being applied to the decipherment of dead ancient languages. Although Barzilay's algorithm relies on the fact that Ugaritic alphabet can be mapped directly to the Hebrew alphabet—and this is certainly not the case for most undeciphered texts, these new technologies can potentially be expanded to become more powerful given the specific peculiarities of different lost languages. As research in machine learning develops, their work can be adapted more readily for other language processing tasks including the closely related field of machine translation.

Life, the Universe, and Sum of Cubes: Finally an Answer for 42

By Joy An '23

Graphic by Heidi Lei '20

$$x^3 + y^3 + z^3 = \underline{\underline{42}}$$

42 as the sum of three perfect cubes, an example of a Diophantine equation.

In 1954, mathematicians from the University of Cambridge proposed a challenge to prove whether or not there are integers x , y , and z that satisfy the equation $x^3 + y^3 + z^3 = n$ for each positive integer n . This type of equation, where all the variables must take integer values, is known as a Diophantine equation. Although this conjecture is easy to understand, the mathematical community has yet to give a complete answer. But mathematicians are one step closer to an answer with the discovery of a solution for $x^3 + y^3 + z^3 = 42$ by Andrew Booker and Andrew Sutherland: $(-80538738812075974)^3 + 80435758145817515^3 + 12602123297335631^3 = 42$. The values for x , y , and z appear to be obscure, random numbers taken from thin air, but they are the result of 1.3 million hours of computing on a global grid of computers.

For one set of numbers, it is relatively simple to show that no solutions exist, and that is when the number n has a remainder of 4 or 5 when divided by 9. This is because all cubes either have a difference of 1, -1, or 0 with the closest multiple of 9, so the sum of three cubes will have a difference between 3 and -3 with the closest multiple of 9. The small cases of $n = 1, 2$, and 3 were quickly solved, and the solutions of these cases could be used to find solutions for any n that was 1, 2, or 3 times a perfect cube. Around the 1910's, mathematicians were able to construct solutions for slightly larger numbers using the solutions to $n = 1, 2, 3$; however, after these families of solutions were found, they were stumped—humans

simply didn't have the computing power to solve larger cases. No major breakthroughs were made until 2009, when Andreas-Stephan Elsenhans and Jörg Janelle created an algorithm, based on the theories of Noam Elkies, that could search for all solutions with n less than 1000 and $\max(|x|, |y|, |z|)$ (the largest value amongst the absolute values of x , y and z) less than 10^{14} . With this algorithm, solutions were discovered for all $n < 100$ that did not have a remainder of 4 or 5 when divided by 9 - except for 33, 42, and 74, three values that continued to elude mathematicians.

After these families of solutions were found, they were stumped—humans simply didn't have the computing power to solve larger cases.

The solution for 74 was discovered by Sander Huisman in 2016, who extended the algorithm used by Elsenhans and Janelle to $\max(|x|, |y|, |z|)$ less than 10^{15} , but 33 and 42 remained unsolved, and many mathematicians theorized that there were no solutions for either number. Then, in February of 2019, University of Bristol mathematician Andrew Booker stumbled upon a YouTube video posted by Numberphile, a channel sponsored by the Mathematical Science Research Institute of Berkeley, California, that discussed the un-

cracked problem of 33. Booker decided to try his hand at solving the problem, and created an algorithm that relied on the minimum of $|x|$, $|y|$, and $|z|$ instead of the maximum. In just three weeks, he found an answer: $33 = 8866128975287528^3 + (-8778405442862239)^3 + (-2736111468807040)^3$. Now, the only unsolved number under 100 was 42. Booker enlisted the help of MIT mathematician Andrew Sutherland. He soon realized that solving 42 would be more difficult and would require more computing power than a single computer, so he turned to Charity Engine, a program that links home computers with other computers across the globe to use their spare computing power. After 1.3 million hours of computing, Booker and Sutherland finally found the solution for 42. The only unsolved cases under 1000 that remain are 114, 165, 390, 579, 627, 633, 732, 906, 921, and 975, for which Booker and Sutherland are working on expanding their algorithm.

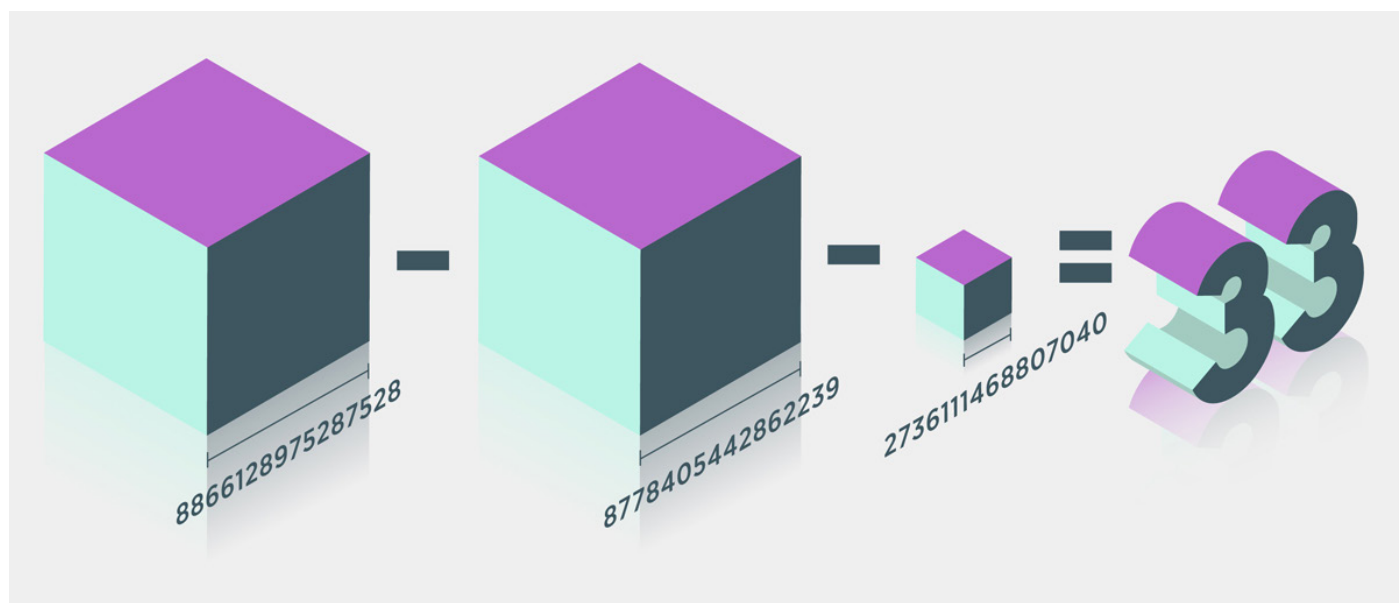
Up until now, the decidability of the sum of three cubes problem remains unknown: Mathematicians still cannot prove whether or not there is an algorithm that can, within a finite amount of time, return a solution for any value n . This problem relates to the tenth problem of Hilbert's 23 problems, which were proposed by David Hilbert in 1900 as a list of the most challenging and influential unsolved problem at the time. His tenth problem asked if there is an algorithm that could decide whether any Diophantine equation had a solution. In other words, is every Diophantine equation decidable? Hilbert's tenth problem has been solved, and the

answer is no; such an algorithm does not exist. The solution was the result of 21 years of combined effort by Martin Davis, Yuri Matiyasevich, Hilary Putnam, and Julia Robinson. While no general algorithm exists for Hilbert's tenth problem, the sum of cubes problem remains open.

This problem relates to the tenth problem of Hilbert's 23 problems, which were proposed by David Hilbert in 1900 as a list of the most challenging and influential unsolved problem at the time.

Solvable or not, the progress made on the sum of cubes problem thus far is impressive and serves as a reminder of how powerful the mathematics community is when it works together. It was a video produced in Berkeley, California that inspired a UK mathematician, an American mathematician, and a global grid of computers to find a solution for $n = 42$. With increasing links between mathematicians all around the world through the internet and the exponentially rising computing power we are capable of harnessing, the boundaries of what we can accomplish are constantly being expanded. Booker and Sutherland serve as proof that, when we harness innovation, we can truly solve the unsolvable.

Graphic from Lucy Reading-Ikkanda/Quanta Magazine



33 as the sum of three perfect cubes, an example of a Diophantine equation.



Apple September Event: The New iPhone, Apple Arcade and More

By Ryan Kim '23

Just like every year since 2017, 2019's edition of the Apple September Event was held at the Steve Jobs Theater at 1 Apple Park Way, Apple's headquarters.

iPhone 11, iPhone 11 Pro, and iPhone 11 Pro Max

The most important release from this year's September Event has to be the newest members of the iPhone family: iPhone 11, iPhone 11 Pro and iPhone 11 Pro Max. Equipped with what Apple touts as the toughest glass ever on a smartphone and milled from a single sheet of glass, the new iPhone is made to resist damage from drops and scratches. The iPhone 11, the successor to the much loved iPhone XR, will come in six new colors: purple, white, yellow, green, black and Product Red, while the iPhone 11 Pro and iPhone 11 Pro Max will come in four colors: silver, gold, space gray and a brand new, sleek midnight green.

Both phones are equipped with Apple's new industry-leading processor, the 7nm A13 Bionic, which has not only 8.5 billion transistors, but also the fastest CPU and GPU ever in a smartphone. The CPU, GPU, and neural engine of the A13 are all optimized for machine learning. Thanks to new machine learning accelerators, the A13 can conduct a trillion operations per second. Moreover, both devices have IP68 water resistance ratings, meaning that the iPhone 11 is water resistant up to 2m underwater for 30 minutes while the iPhone 11 Pro and 11 Pro Max are water resistant up to 4m underwater for 30 minutes.

However, the similarities between these two phones end here. The iPhone 11, like the XR before it has a 6.1 inch LCD display, with a 1792 by 828 pixel resolution at 326 ppi (pixels per inch). On the other hand, the iPhone 11 Pro and Pro Max have 5.8 and 6.5 inch Organic LED displays respectively, with 2436 by 1125 and 2688 by 1242 pixel resolu-

tions, both at 458 ppi, which is the same as the iPhone X, iPhone XS and iPhone XS Max.

The new iPhone 11 has two 12MP (Mega Pixel) cameras, one wide and one ultra wide while the Pros have an additional telephoto camera that allows them to have 10 times optical zoom compared to the 11's 5. Lastly, all phones are speculated to have 4GB of RAM (Random Access Memory) and are offered with 64, 256 and 512GB of storage. Available from September 20th, the iPhone 11 starts at \$699 while the iPhone 11 Pro starts at \$999 and the iPhone 11 Pro Max starts at \$1099.

Apple Arcade

Although the release of the new iPhone models was definitely the highlight of the event, the keynote did not begin with them, but rather with the introduction of Apple Arcade, the newest addition to Apple's burgeoning services branch. Available exclusively on the App Store, the game subscription service for mobiles, desktops and TVs gives unlimited access to over a hundred new games created by Apple in cooperation with various other innovative game developers. Apple Arcade will be

available starting September 19th with a family subscription fee of \$4.99 a month, which includes 1 month free trial.

Apple TV+

Apple TV+ is Apple's new subscription based streaming service available for all Apple devices. Available from November 1st in over 100 countries, a family subscription fee will be \$4.99 a month. Even better, if you buy an iPhone, iPad, Mac or Apple TV, one year of Apple TV+ will be included.

Graphic from Apple Inc.



The six color options of the new iPhone 11.

iPadOS and 10.2" iPad

The newest addition to the iPad is iPadOS, an operating system derived from iOS and designed specifically for the iPad. It will be available to all Choate students free of charge once permission is given from the IT Department. Apple claims the new iPadOS "adds new capabilities and intuitive features that are specific to the large display and versatility of iPad." Among them

**The New iPadOS
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include new simplified multitasking and app sliding functions, a new smaller screen keyboard that can be accessed by pinching the preexisting keyboard, along with the ability to crop videos and SD card and thumb drive support among other functions. In addition, Apple released the 7th generation budget iPad, now equipped with a new 10.2" retina display and powered by Apple's A10 Fusion chip (the same chip that powered the iPhone 7 and 7 Plus, which were introduced back in 2016). Moreover, the smart connector and Apple Pencil support has finally arrived to the new iPad, which will be priced at \$329, available September 30th. Last but certainly not least, the enclosure of the new 10.2" iPad is made from 100% recycled aluminum.

Apple Watch Series 5

Apple Watch has been the staple of practical smartwatches ever since its release back in April of 2015. From a design standpoint, Apple Watch Series 5 is virtually identical to its predecessor, the Series 4. However, the new watch has a retina always-on display, which dims instead of shutting off when it senses you are not looking at it. Despite having the screen on at all times, the new Apple Watch still maintains 18 hours battery life, the same as the previous Apple Watch thanks to energy optimization. Additionally, the new Apple Watch has a built in compass, which can be used in both the Compass app and Maps. Every cellular equipped Apple Watch Series 5 is equipped with international emergency calling, allowing you to call over 150 different emergency services from around the world. For the first time, the App Store will come to the Apple Watch via WatchOS 6, allowing developers to create Apple Watch orientated appli-

cations. Moreover, new useful apps for the Watch have been added such as the Noise app, which measures the decibel count of your surrounding area and alerts you if something is too loud, and the Cycle Tracking App which makes it easier to log information, keep track of your menstrual cycle and receive alerts when your period is likely to begin. Lastly, in addition to several new watch faces being announced, Apple revealed the Apple Watch Studio, a place where you can mix and match an Apple Watch to see what it is like before buying it. Apple proudly claims that there are nearly 1000 different ways to select your Apple Watch and are offering dozens of colors and textures of watch bands in addition to four different cases: ceramic, aluminium, stainless steel or titanium.

While the contents of this year's September Event certainly were not the most unexpected, it did include some welcomed additions to the Apple ecosystem.

Graphic from Apple Inc.



The new 10.2" iPad, complete with Apple's new iPadOS.

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