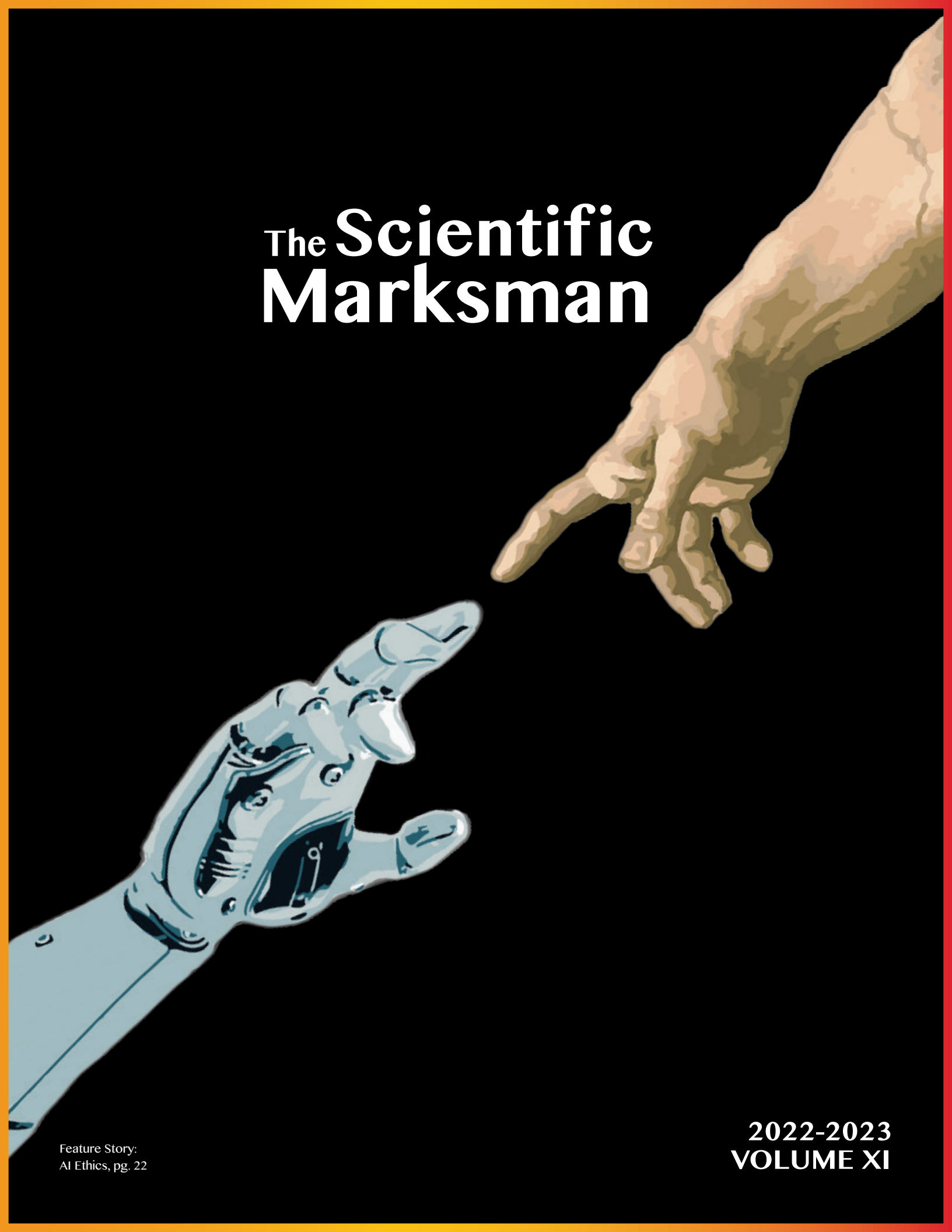
The Scientific Marksman



Feature Story:
AI Ethics, pg. 22

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The Scientific Marksman

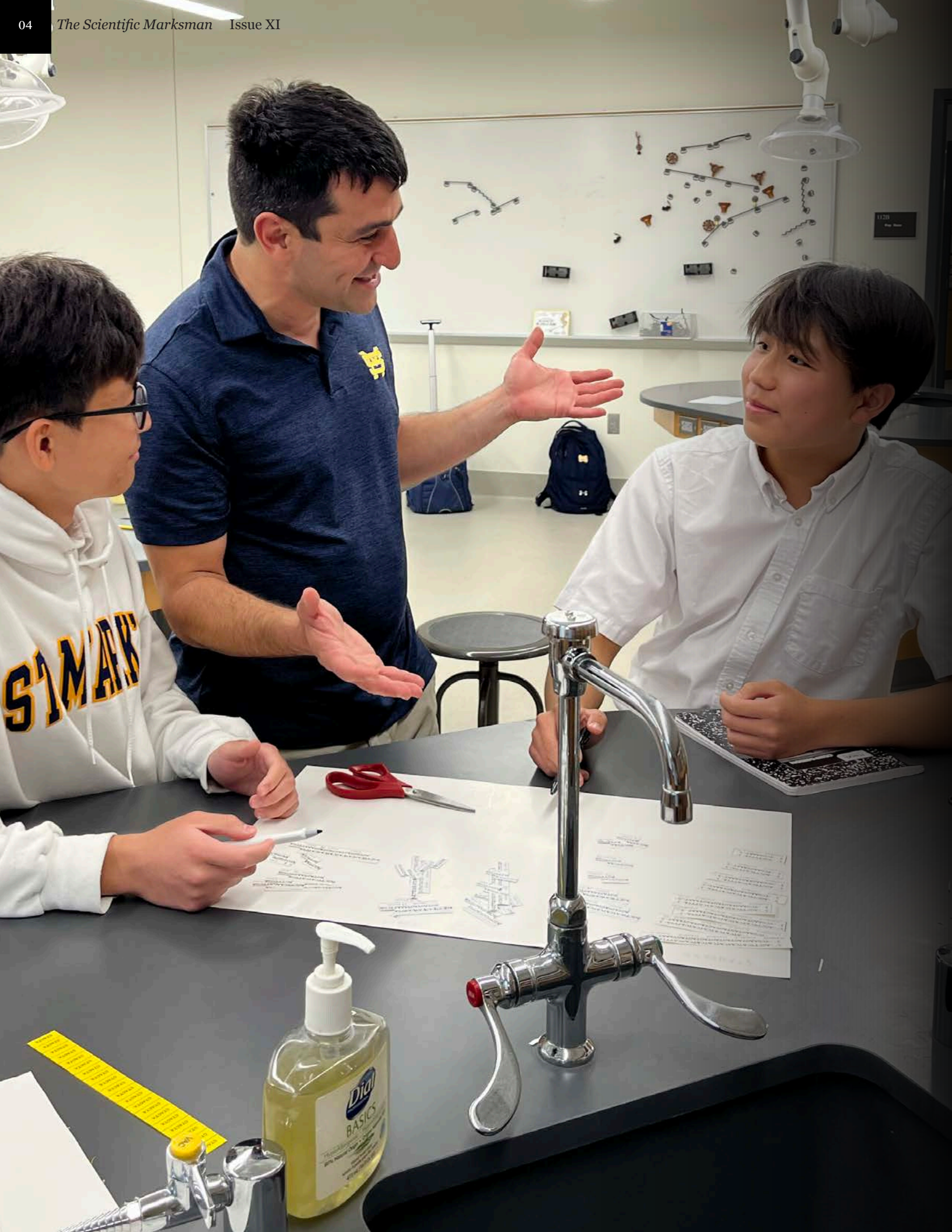
Editors' Note

Artificial intelligence. In the past year, it's been one of the most-discussed topics within the whole STEM community. Whether you're an expert in the field, a curious author, or even a middle school student, chances are, you have played around with ChatGPT and DALLE2.

With this year's magazine, we wanted to take a look at the details. The ethics in implementation. The implications applications. And most of all, how it works.

From data collection to algorithm training and deployment, Edition XI of *The Scientific Marksman* explores how STEM and AI fit in the world today. And in the process, discover the "AI Brain" developing in St. Mark's constantly-growing community of scientists.

Co-Editors-in-Chief
Michael Gao '23, Aaron Liu '23


Dial
BASICS

Dedicatee:

Dr. Dan Lipin

Publishing a magazine is grueling. It takes time to brainstorm themes. It takes effort to coordinate people. It takes grit to push all the way through. For the past year, Dr. Dan Lipin has been instrumental to the design and writing process. His love for science, his positive demeanor and his contagious smile have never failed to light up our design nights, even when the clock struck twelve.

Our staff is eternally grateful to Dr. Lipin. We truly applaud him for his sacrifice. Without him, there would be no magazine. For everything he has done, we dedicate this edition of *The Scientific Marksman* to him.

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Section I: DATA

Data. It pervades the world around us—the number of students at St. Mark's, the probability of a coin flip, the chance that your favorite sports team will win the championship. It's anything noteworthy, awesome, or interesting that scientists jot down, share and write about. In the world of AI, data is what drives algorithms—it is the stalwart foundation of the AI brain. In the real world, that's any information we can gather, from seemingly trivial findings to theories explaining the scientific world. Every experiment in history has yielded some sort of new data, the driving factor for humankind's understanding of the vast world around us. This section of *The Scientific Marksman* explores novel data that scientists have discovered, shifting our view of the world in unforseen ways. "Data in Medicine," this section's capstone story, explores the cutting-edge technology that medical experts use to identify and treat diseases. Whether peering into the universe, studying human psychology, or assembling complete models of the human body, data has paved the path for present and future researchers, accelerating our understanding of our planet and beyond.

Data In Medicine

By collecting data and statistics from a massive array of tissue samples, doctors can discover the mechanics behind a disease's infection of the body. With this newfound knowledge, scientists will know which part of the disease or body to target with their new drugs.

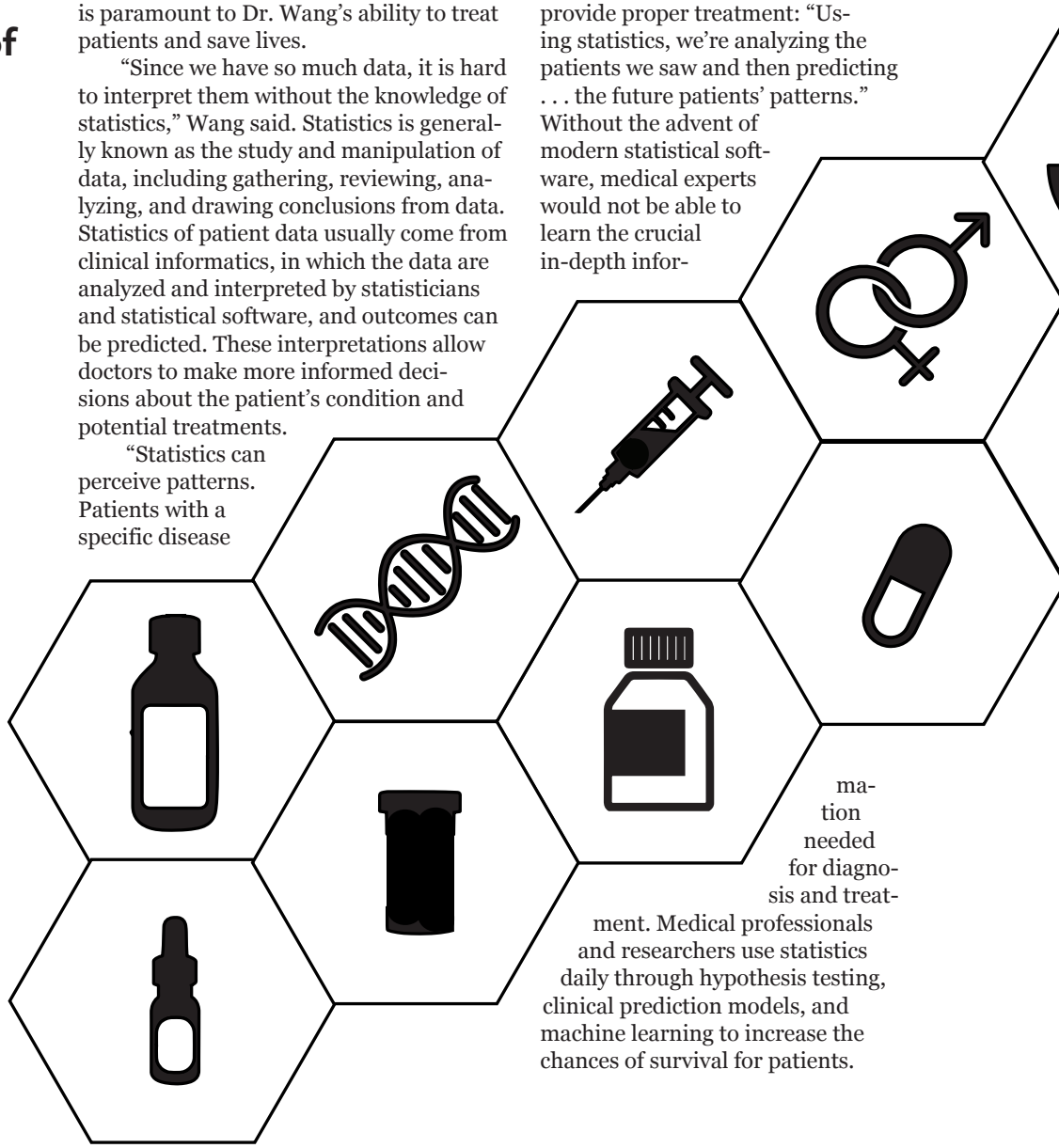
Statistics is essential to medicine because analyzing and interpreting data will provide doctors and practitioners with evidence-based results. With the increase of high-tech medical tools at our disposal, more and more data is being generated, intensifying the need for proper statistical analysis.

Dr. Hao Wang is an ER physician who works in Emergency Medicine. In the E.R., a lot of information comes from electronic medical records documenting the patient's condition, so proper data analysis is paramount to Dr. Wang's ability to treat patients and save lives.

"Since we have so much data, it is hard to interpret them without the knowledge of statistics," Wang said. Statistics is generally known as the study and manipulation of data, including gathering, reviewing, analyzing, and drawing conclusions from data. Statistics of patient data usually come from clinical informatics, in which the data are analyzed and interpreted by statisticians and statistical software, and outcomes can be predicted. These interpretations allow doctors to make more informed decisions about the patient's condition and potential treatments.

"Statistics can perceive patterns. Patients with a specific disease have their clinical presentation, lab values, and clinical courses fall into specific patterns. Using statistics, doctors can discover common patterns and risk factors affecting patient outcomes, which will help us to find medications that will bring the best clinical outcome," Dr. Wang explained.

Dr. Wang said that he sees many patients with various problems. His job is to recognize a patient's problems and correctly provide proper treatment: "Using statistics, we're analyzing the patients we saw and then predicting . . . the future patients' patterns." Without the advent of modern statistical software, medical experts would not be able to learn the crucial in-depth information needed for diagnosis and treatment. Medical professionals and researchers use statistics daily through hypothesis testing, clinical prediction models, and machine learning to increase the chances of survival for patients.



I. Hypothesis Testing

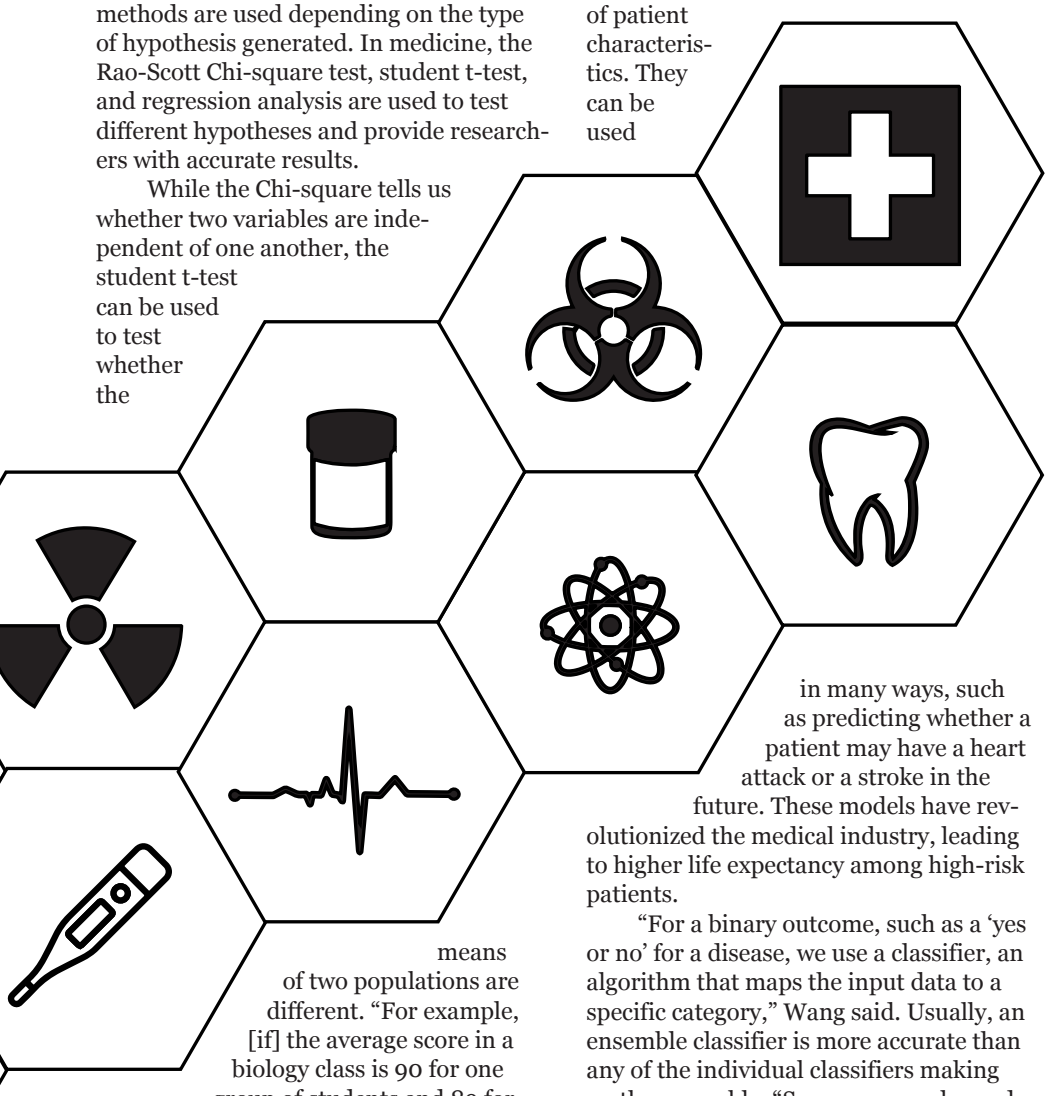
Statistics can be used to test different hypotheses in the medical field. This is called hypothesis testing, which is essential to researchers for making conclusions about their claims and finding the overall significance of their results. Various statistical methods and measures are available to provide evidence supporting or against a particular hypothesis. Different methods are used depending on the type of hypothesis generated. In medicine, the Rao-Scott Chi-square test, student t-test, and regression analysis are used to test different hypotheses and provide researchers with accurate results.

While the Chi-square tells us whether two variables are independent of one another, the student t-test can be used to test whether the means of two populations are different. "For example, [if] the average score in a biology class is 90 for one group of students and 89 for another, can we say that the group with a score of 90 is better than the group with a score of 89? It depends on the statistical analysis and whether the difference is statistically significant," Dr. Wang said. Without these hypothesis-testing tools, it would be near-impossible to determine if there's statistical significance between two data sets.

Another commonly used statistical method is multivariate logistic regression analysis, which calculates the probability of an event depending on multiple sets of variables. "For example, when you want to identify risk factors for cancer, such as age, gender, education level, and smoking status, you would use [multivariate logistic regression analysis] to analyze all these factors together and identify which factor(s) predict the likelihood of developing cancer in the future," Dr. Wang explained.

II. Clinical Prediction Models

Clinical prediction models are tools that compute the risk of an outcome given a particular set of patient characteristics. They can be used in many ways, such as predicting whether a patient may have a heart attack or a stroke in the future. These models have revolutionized the medical industry, leading to higher life expectancy among high-risk patients.



"For a binary outcome, such as a 'yes or no' for a disease, we use a classifier, an algorithm that maps the input data to a specific category," Wang said. Usually, an ensemble classifier is more accurate than any of the individual classifiers making up the ensemble. "Some commonly used machine learning algorithms to predict the binary outcome include random forest, decision tree, and XGboost."

Sometimes the outcomes are continuous, not binary, variables. These variables don't have "yes or no" options, instead possessing a continuous spectrum of outcomes. An example of a continuous variable is the length of time a person waits in the waiting room to see a doctor.

"You may wait for five minutes, or you may wait for ten minutes. You must use other methods (to predict specific outcomes), including linear regressions, since they make predictions based on continuous variables." Dr. Wang explained. "So, it's hard to say what statistical method you use for particular models. It all depends on what kind of hypothesis and variables you choose."

Clearly, a statistician must have strong background knowledge to perform the correct medical tests specific to a particular disease or patient.

Besides clinical prediction models, statistics can also be used for other purposes, such as determining the effectiveness of different medications.

"For instance, when treating a patient, it is important to determine which medication is more effective than others and the differences in the side effects of these medications. Statistics can be utilized to assess the severity of side effects," Dr. Wang stated.

Based on the statistical data, doctors can decide to avoid medications with severe side effects and opt for those with milder side effects.

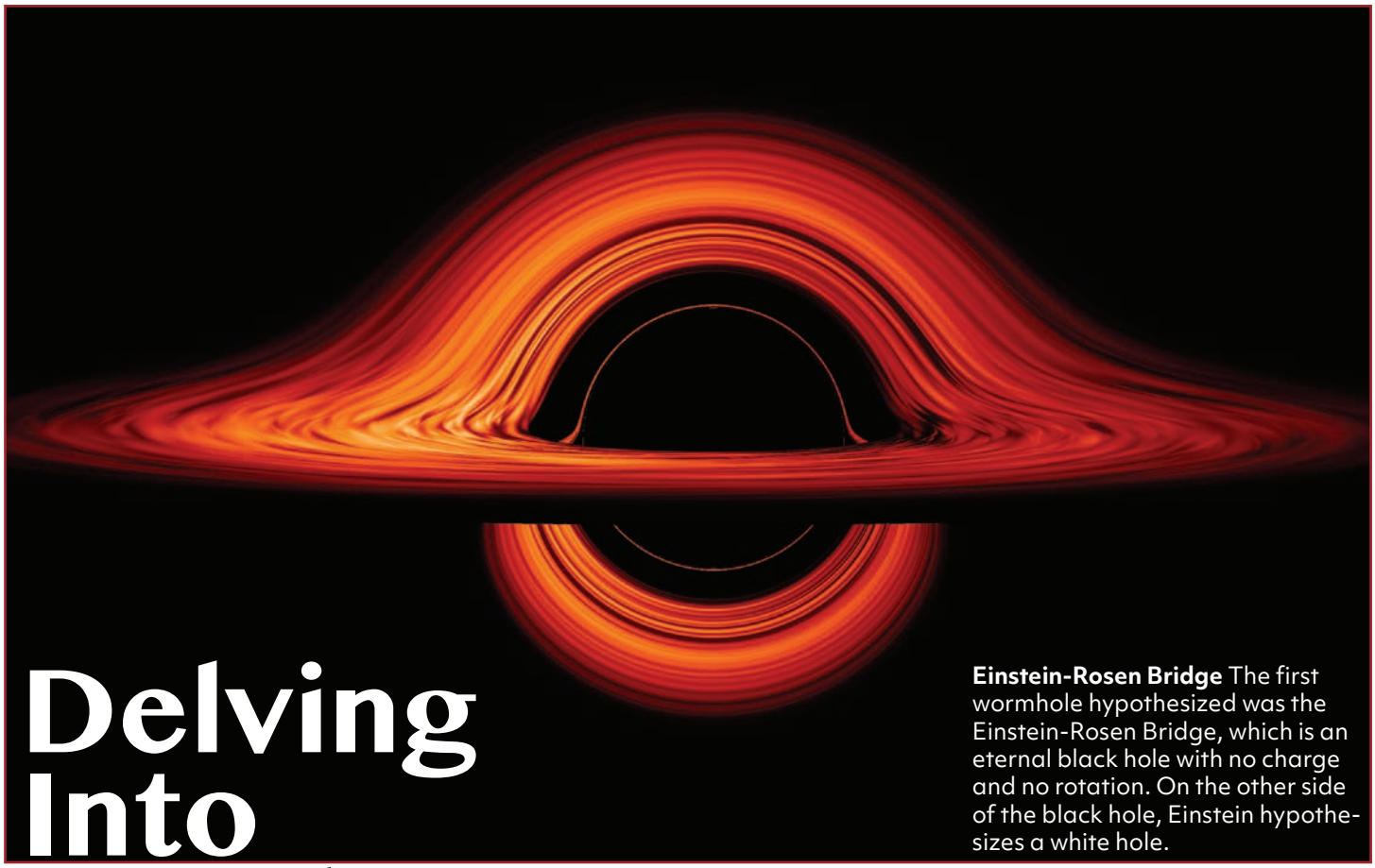
"Predictions in medicine have become more accurate due to real-world data and advanced statistical software availability," Dr. Wang said.

III: AI and Advancements

For Dr. Wang, the advent of AI algorithms and machine learning has completely changed the medical statistics playing field.

"Artificial intelligence and machine learning are [both] growing in popularity." Dr. Wang said. "So now, doctors need more and more background in statistics. Artificial intelligence and machine learning algorithms can be used to predict a model. Those models can help . . . physicians to predict the patient's outcome. In the next 5-10 years, with more advanced machine learning and artificial intelligence, these technologies can help physicians recognize disease patterns. Especially when disease[s] are rare, and . . . [aren't commonly diagnosed], using artificial intelligence to identify the patterns will help the physician recognize . . . [them]. I think this will be the future trend. Physicians use machine learning algorithms to read samples, including pathological slides and CT or MRI results."

Story Alex Pan, Richard Wang
Graphic Michael Gao



Einstein-Rosen Bridge The first wormhole hypothesized was the Einstein-Rosen Bridge, which is an eternal black hole with no charge and no rotation. On the other side of the black hole, Einstein hypothesizes a white hole.

Delving Into Another Dimension

Physics C instuctor, Wesley Irons, discusses the possibility and impact of wormholes and what it means for space travel.

Travel through the universe is limited by the constant c, representing the speed of light in a vacuum: about 300 million meters per second. In the Apollo 10 mission, humanity went the fastest it has ever gone - a measly 0.00004c. But what if there was an easier way? What if humans could circumvent expending the massive energy it would take to travel faster and instead take a shortcut through space-time? These holes in space-time, aptly named "wormholes," would revolutionize travel through the cosmos. And since its conception less than a century ago, it's warranted and maintained broad discussion.

"The first in-depth description of wormholes was formulated by Albert Einstein in 1935," Physics instructor Wesley Irons said. "At the time, Einstein had just finished his field equations (a set of formulations that described how matter relates to the shape of space-time) and came up with the idea of a black hole—an infinitely dense region of space. From the same equations, Einstein also theorized the idea of white holes, areas which no particles or light can enter, and wormholes, where the warping of space-time could connect two distant spaces."

Unfortunately, shortly after Einstein's discovery spread throughout science, astrophysicists quickly realized that large-scale wormholes were physically impossible.

"People eventually found out that wormholes would violate the very prin-

ciple upon which the theory of relativity was built—namely, causality," Irons said. "Einstein's field equations, which he used to first hypothesize wormholes, didn't describe much about the direction of cause and effect, but we eventually figured out that wormholes simply wouldn't obey the fundamental principles of time as we know it."

Although this revelation may make wormholes seem impossible, there might still be hope for them. Einstein's theory of General Relativity, the foundation upon which he built the idea of the wormhole, is still a relatively young field of physics. New discoveries or breakthroughs will inevitably modify the theory. In fact, discoveries today are already impacting and changing our understanding of general relativity.

"Physicists are currently playing around with quantum gravity, a field which aims to describe gravity according to the principles of quantum mechanics," Irons said. "It is likely that with a proper quantum gravity theory, the [undesirable] consequences of the bizarre and fascinating geometries of wormholes will vanish."

To explore wormholes through the lens of quantum gravity, researchers have recently started to develop small-scale wormholes with quantum computers. At the California Institute of Technology, one such investigator, Maria Spiropulu, simulated a wormhole composed of two connected black holes.

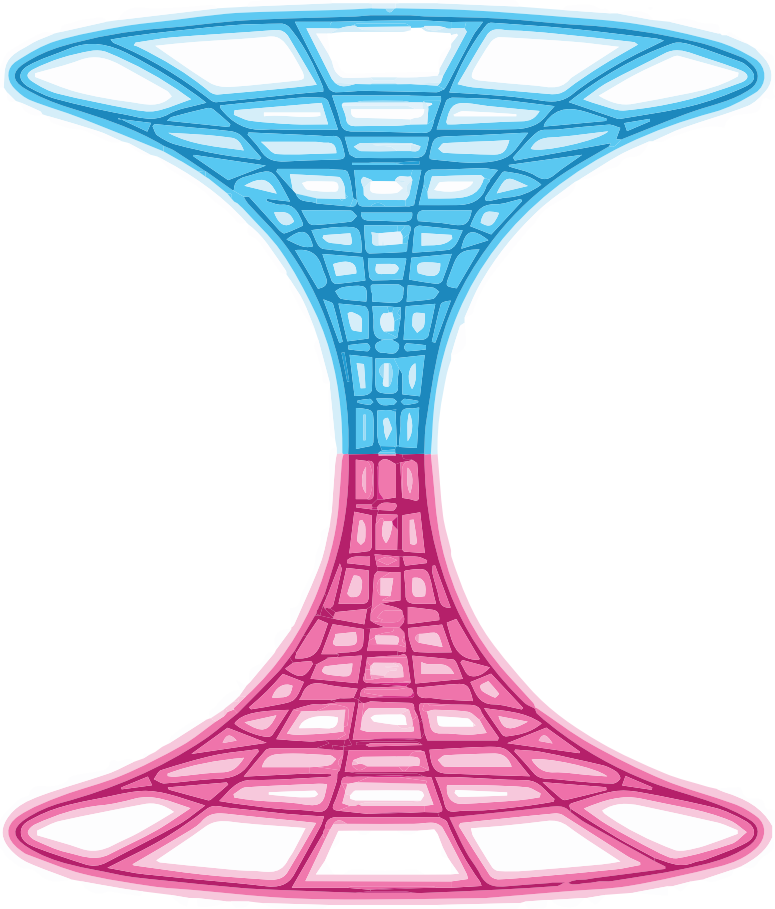
Naturally occurring wormholes may also exist. Some scientists believe that shortly after the Big Bang, quantum fluctuations in the fabric of space-time may have created tiny wormholes. The universe expanded several light-years in the following moments, meaning the small tears grew into full-size wormholes. This theory, founded upon the principles of string theory (a field that claims that the universe is composed of one-dimensional "strings" which vibrate and interact), has led many of its supporters to claim that supermassive black holes, such as the one at the center of the Milky Way, may actually be wormholes.

If humanity manages to discover real wormholes of any type in the future, they could be used in many different ways. For example, many science fiction writers have popularized the idea that wormholes could be used for near-instantaneous trips across the universe. Along with physical transportation, physicists theorize that wormholes could also be used for time travel. For instance, if one "end" of a wormhole is accelerated to high speeds and brought to the origin of the other, time dilation—the slowing of time as one travels closer to speed "c"—would cause any human who enters the high-speed end of the wormhole to come out at the other side younger than they entered.

For now, practical wormholes remain a distant possibility for future humans to uncover. Even though current-day scientists may not be able to manipulate and generate wormholes effectively, Irons believes that their attempts to make the idea a reality will teach individuals across the world valuable lessons about what it means to be a human.

"We should still continue to expand upon the science which interests us," Irons said. "If we continue to do what we've been doing, we may manifest a reality that is bigger, better and perhaps much scarier than ours. Along the long the way, we may learn more about humanity's values and ideals."

Story Vardhan Agnihotri, Sohum Sukhatankar
Graphic Michael Gao, NASA (left)



Graphical Representation
To better visualize a wormhole, physicists imagine that spacetime is a patchwork quilt with folds, bends and tears. A wormhole would be a hole in the fabric connecting two points of spacetime together.

Stained to the Bone

Mark Adame, the Cecil H. and Ida Green Master Teaching Chair in Science, preserves the structures of animals through a process of clearing and staining.

First Time
This is Mr. Adame's first cleared and stained specimen—the rat that started it all.

Story Michael Gao
Photos Michael Gao

Stepping into Mark Adame's office is like venturing into a mad scientist's laboratory. On one end of the room, a stack of papers with rough calculations etched onto them. On the other, a fridge—hiding away animal carcasses and other specimens behind its vast, stark-white doors. For the brave souls, a row of animal skulls lies on display in the classroom's back closet. But amid all the lab reports and displays, one collection stands out: myriad jars of cleared and stained animals.

Fascinated by the Natural History Museum's colorfully-preserved specimens, Master Teaching Chair Mark Adame has made it his goal to grow a collection that rivals his inspiration—a goal that started from a free-time discovery.

"I got the idea a few years back watching a YouTube video of this girl that worked at the National History Museum," Adame said, "and in one of the episodes, she was showing the museum's collection of clear and stained specimens. It was beautiful."

Afterward, Adame began researching the process and exploring techniques to preserve and stain animal specimens. After perusing numerous articles and scientific documents, Adame landed on a novel procedure of his own.

"I start by ordering the preserved animals from a catalog, and once they arrive, I dissect them without destroying the muscles," Adame said. "I cut them open and pull out all the internal organs, really yanking them out like cleaning a fish. All you really want is the skeleton and the muscles left over."

Then, Adame makes a small incision on the back—shallow enough only to pierce the skin—and carefully rips the skin piece by piece. Once the specimen is thoroughly cleaned and gutted, Adame soaks the animal in a series of caustic agents and staining solutions.

"I usually soak them in a series of hydrogen peroxide and sodium borate solutions, each time with increasing concentration," Adame said. "Then, I use trypsin to break down—but not completely destroy—the proteins, which allows for more of the soaps and the peroxide to get into the tissue."

As more of the chemical solution soaks into the muscles, they turn translucent in a process called "clearing."

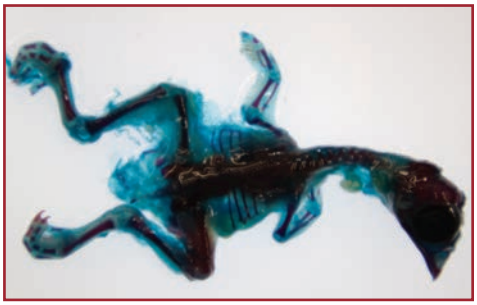
"Once I get to a certain stage of translucency, I start the staining process," Adame said. "I let them soak in this blue Alcian dye that binds and stains the cartilage. Then, I soak it in another saturated solution of sodium borate to get the excess dye out."

Adame repeats this process with a red Alizarin dye to color-code bones. After clearing out excess dye with a solution made of trypsin, sodium borate, and hydrogen peroxide, Adame preserves the final product in glycerin.

While it started as a fun personal hobby, Adame's growing collection has caught the eye of some of his students throughout the year, and he's even gone through the whole process with a few curious students.

"It's amazing what some of these students can do," Adame said. "They know the process like the back of their hand after reading the procedures only once. And they're not even squeamish about touching the animals."

While his students may be less skilled than their teacher, Adame is hopeful that activities like these can inspire a life-long interest in biology among the students he teaches. And who knows? One day, his collection might just surpass the Natural History Museum's.



Gallus gallus
Cleared and stained chicken embryo

Rattus norvegicus rattus
Cleared and stained lab rat

Gambusia affinis
Cleared and stained mosquitofish

Cyprinella lutrensis
Cleared and stained red shiner

HOOKED

In recent years, with the advent of more potent drugs like fentanyl, addiction has resurfaced as a new problem gripping the nation. To combat this, Dr. Mary Bonsu, school psychologist, promots awareness around the signs of addiction and provides valuable insight on drug tolerance.

Addiction. Nowadays, it's almost a catch-all phrase—applied to substance abuse, video games, or even activities like sports gambling. But what does it actually entail, scientifically, in psychology? While there's no consensus definition of addiction, Upper School Counselor Dr. Mary Bonsu proposes a two-part definition.

"An addiction occurs when someone is either physically or psychologically dependent on something," Dr. Bonsu said. "That something could be a substance, or in other cases, an activity."

Signs of an addiction include significant behavioral changes and physical responses, which allow psychologists to differentiate it from an intense liking of an activity or substance. Mentally, someone with an addiction would be willing to go to significant lengths to engage in their addiction, sometimes forgoing relationships or taking dangerous risks regarding their career and life. But, regarding the brain's response to addiction, one common and significant sign is the development of tolerance.

Tolerance is characterized by "a person's diminished response to a drug that results from repeated use," according to the University of Toledo. After each new use, the brain requires more of the particular substance or activity to reach the same "high" level, becoming extremely dangerous over time, with desired levels of consumption snowballing.

Tolerance, however, does not necessarily indicate an addiction. For proper diagnosis, factoring in other warning signs, such as sacrificing sleep and holding on to a mantra of "I can stop whenever I can," is also necessary. Furthermore, determining the causes of addictions remains a scientific challenge. Psychologists often avoid using the definitive word "cause," preferring "correlate" instead.

"In Psychological Science, we generally avoid the word 'cause' without evidence of a direct causal link to something," Dr. Bonsu said. "It would require experimentation to say 'this' absolutely causes 'that.'"

On the other hand, correlation does not determine causation but instead shows risk factors and the likelihood of gaining an addiction with the help of statistical data and analysis. Many addictions are correlated with heredity, and newer studies deal with "primary attachment," which relates to the nature of someone's attachment to their parents.

"The original attachment relationship is the parents, but then, the way attachment styles play out is how you relate to people," Dr. Bonsu said. "So, if you can't get close to people and feel insecure in relationships, you are uncomfortable with intimacy. The theory suggests drugs and alcohol can sort of fill that void."

"An addiction occurs when someone is either physically or psychologically dependent on a something," Dr. Bonsu said. "That something could be a substance, or in other cases, an activity."

Fortunately for those with an addiction, the field of psychology has dedicated lots of time and research to treating addiction. Most programs are two-pronged, with a focus on both medication and counseling. Firstly, specific medications exist for specific substance recovery. According to the Substance Abuse and Mental Health Services Administration, medications like buprenorphine, methadone, and naltrexone are used to treat Opioid Use Disorder, and they "operate to normalize brain chemistry, block the euphoric effects of alcohol and opioids, relieve physiological cravings, and normalize body functions without the negative and euphoric effects of the substance used." At the same time, counseling supplements treatment. Dr. Bonsu believes that "the counseling aspect is for giving you solid skills for seeking other things in life out that are pleasurable but also aren't addicting."

Studies have consistently shown that meditation and mindfulness programs can help people manage their addictions. Additionally, many communities have organizations dedicated to improving the quality of life for addicts. For example, many organizations, especially those that specialize in treating alcohol addiction, have some form of a 12-Step program. First created and implemented by Alcoholics Anonymous, the program includes helping addicts commit to steps like "admitting powerlessness over the addiction" and "believing that a higher power (in whatever form) can help." In every marker of sobriety or recovery from the addiction, the addict may receive recognition from the community or organization.

However, the main challenge for addiction recovery is relapse, where an addict in recovery returns to the addictive behavior they engaged in before. Many alcoholics, even after years of sobriety, refuse even to sip small amounts of alcohol for fear of relapse, pointing out why discipline and commitment to steps in the 12-Step Program are crucial for addiction recovery. Many programs for addiction recovery, including Alcoholics Anonymous, require, when one shares their story, to introduce themself as an alcoholic as a reminder of the dangerous potential of relapse, which is why Dr. Bonsu explains that addiction is considered a disease by some.

While we often only hear stories of severe cases, addiction is common and all around us. In today's world, even activities like gambling have become a concern. While data is not extensive yet, Dr. Bonsu is "concerned about individuals engaging in any addictive activity when they don't have coping strategies for dealing with stress and their prefrontal cortex is not fully developed." However, it's crucial to look out for those who may be picking up an addiction, and proper and effective treatment can be possible by recognizing the signs of addiction.

Story Akash Raghunathan
Graphics Michael Gao

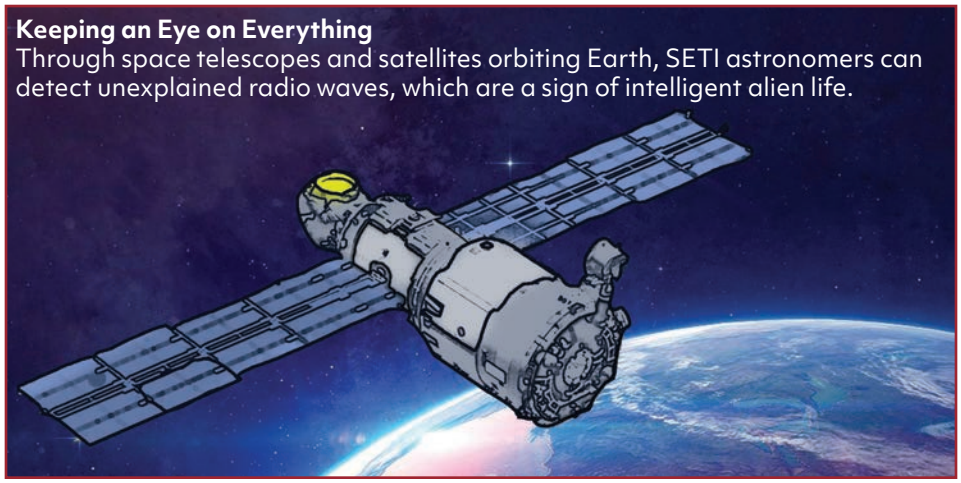
Life Beyond the Clouds

with Wesley Irons

Physics and Astronomy instructor Wesley Irons provides his valuable insight about the probability and the possible locations of extraterrestial life

What's the probability that extraterrestrial life exists? Are there conflicting opinions in the scientific world about this?

Wesley Irons: The universe seems to be quite hospitable to life as we know it—much of what we observe in the universe is similar to what we see on Earth. For life to occur in space, there are a few specific conditions. For one, it must have a planetary system. Stars with higher metallicity are more likely to have planets, and stars increase in metallicity as you move closer to the galactic center—a place with a higher density of stars. However, the increased density of stars also means increased supernova rates, which would likely be a hindrance to the evolution of life. Since supernovae rates are also higher in the spiral arms, a corotation zone is needed to keep potential life-bearing systems from entering the spiral arms. Putting that all together, there appears to be a "galactic habitable zone" from about 7 to 9 kpc from the galactic center. For life to occur, the planetary system's star must also be of a specific type. They must survive in a state of fusing hydrogen for a long enough period. This eliminates the largest stars like O and B stars—it'd likely need one to two billion years for simple life to develop. Similarly, A and F stars have a lot of ionizing radiation (UV), which could pose a problem for life development. K and M stars, which are the smallest ones, live a very long time and are also the most numerous —they constitute about 90% of all stars. However, they are much cooler, and the so-called "habitable zone" would be very close to the star, so close that such a planet would likely be tidally locked to the star, with one side in perpetual daylight and the other in the darkness. Being that close and tidally locked would also require a thick atmosphere to distribute the heat, as well as a substantial ozone layer. Instead, the sweet spot seems to be a G-type star—the same as our Sun. All of this seems to indicate that conditions for life are quite rare. But even with these restrictions, the number of possible life-bearing systems is enormous, especially when you consider how ours is just one galaxy out of trillions in the observable universe. Taking that into consideration, I would say the probability of some kind of life existing elsewhere is rather high. Whether or not we will ever know about it, though, is another question.



Keeping an Eye on Everything
Through space telescopes and satellites orbiting Earth, SETI astronomers can detect unexplained radio waves, which are a sign of intelligent alien life.

What would you expect the first extraterrestrial life we see to look like? A unicellular, primitive creature or a complex, omniscient organism?

WI: That's interesting because it would seem logical that most life would be of the simple kind, and indeed that is what we are looking for in the solar system. We're also looking for evidence of life outside the solar system, but our main hope is to find evidence of microbial life out there, meaning that direct discoveries of life will likely come from within our solar system. We are also actively searching for intelligent life (SETI). It also seems plausible that if there is intelligent life beyond Earth, it would be easier to find, and indeed they may be trying to find us. So, which would be discovered first? I'm not sure.

What does "life" mean? What counts as life, and how will we know when we find it?

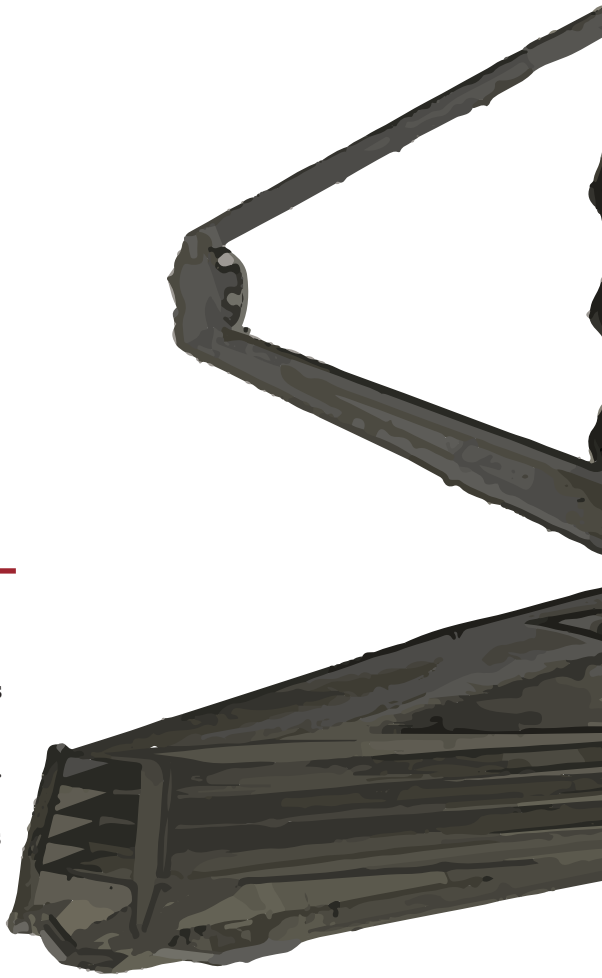
WI: This is a surprisingly complicated question. For one, as far as I know, there is no agreed-upon definition of life. To include things as diverse as people, trees, and bacteria but exclude things like fire and mineral crystals is difficult. Astrobiology has an additional difficulty, which is the question of "what life should look like in a completely different evolutionary environment." At the moment, astrobiologists are interested in the search for "life as we know it," which is a much easier search with easily-measurable success.

Which celestial body in our Solar System (other than Earth) do you think has the greatest probability of harboring life? Which body do you think is most likely to be colonized?

WI: Many objects in the solar system are—and always have been—pretty convincingly inhospitable to life, with Mercury and the Gas giants among them. With others, such as Venus, it's more difficult to determine the existence of prior life. And still, others show remarkable prospects for prior or even current life. But the most promising feature for a planet to contain life is liquid water. On Earth, there is an important stabilizing feedback—plate tectonics—which keeps CO_2 in the atmosphere at the right levels in order to maintain liquid water oceans. Mars is geologically dead today, being cold and barren, but there is much evidence that it was quite active in the past. It is possible that there was liquid water in the past; whether life evolved and later became extinct remains to be determined. Europa is one of Jupiter's moons and is thought to have liquid water oceans below a layer of ice. The evidence for this comes from gravity measurements from Galileo, which have determined that there is a surface layer about 150 kilometers thick, which also has a similar density to liquid water. Even more convincingly, Europa is tidally locked to Jupiter, meaning one side constantly faces the planet. That, combined with its orbit being slightly eccentric due to the other moons, means that there are varying tidal forces, which periodically stretch Europa slightly toward Jupiter and then relax. This tidal flexing could generate enough heat to keep the oceans liquid.

Interview Alex Pan
Graphic Michael Gao
Photo Benjamin Chen

Ad Astra Per Aspera



"To the stars through difficulties." NASA's James Webb Space Telescope, the largest optical telescope in space, houses ultrasensitive and high-resolution instruments that allow it to peer into the void of space and see the first stars or formations of the first galaxies.

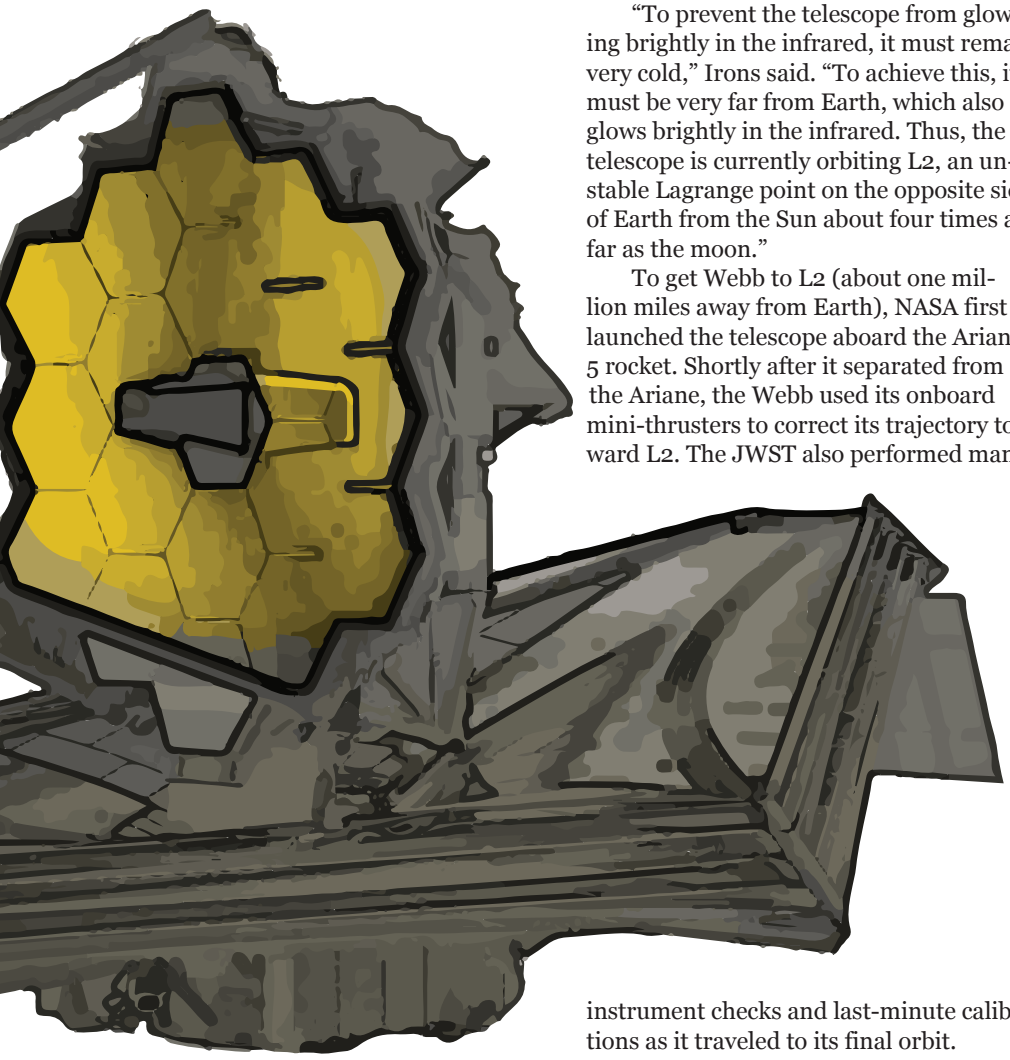
In the vast expanse of space, nearly a million miles away from the planet on which it was created, a telescope drifts through the cosmos. As it floats along its lonely, unexplored path, it snaps image after image. One of an exoplanet. Another of a star. And occasionally, an entire galaxy. All to establish its name as the James Webb Space Telescope (JWST).

The JWST is NASA's latest venture into space imaging, a field that utilizes the unique properties of light to capture images of far-away objects. For over 30 years, NASA relied extensively on the Hubble Space Telescope to take photos of the cosmos. This telescope was able to take incredible pictures throughout its career but was eventually crippled by multiple mechanical failures. As a result, the Hubble was decommissioned, and NASA introduced the JWST, a telescope more powerful and capable than ever before. Of its many upgrades, the JWST's mirror size marks a substantial leap forward.

"James Webb has a 21.3 feet diameter mirror, while Hubble has a 7.8 feet diameter mirror," physics teacher and astronomy enthusiast Wesley Irons said. "That's over seven times more light-gathering power. The increased mirror size also boosts resolving power, or the ability to differentiate far-away objects."

On the back of each of the 18 mirrors, six actuators enable the JWST to fine-tune its view of the universe. Once the JWST is ready to take a photo of this view, the 18 mirrors, arranged in a nearly parabolic shape, direct light into the central instruments of the telescope, which mainly consist of electromagnetic sensors and cameras. After the image is formed, the Webb uses its high-frequency radio transmitter, attached to the rear of the spacecraft, to beam pictures back to Earth. Using these advanced technological systems, the JWST has taken high-quality images of Neptune's and Jupiter's rings, the Large Magellanic Cloud (a satellite galaxy of the Milky Way) and the Tarantula and Carina Nebulae, along with many more stars and exoplanets.

In addition to allowing JWST to take fantastic photographs of our cosmos, the telescope's improved abilities will allow us to piece together the history of our universe. By peering deep into the cosmos, the JWST is actually photographing past cosmological events. The further away an object in space is, the longer it takes for its



light to reach the Earth. The finite speed of light means that by looking far away, the telescope is receiving "old" light that we're just now receiving, painting a scene of early stars and planets formed close to the beginning of our universe. In this regard, another one of the telescope's upgrades—IR sensors—has allowed it to observe more information than ever.

"James Webb is primarily an infrared telescope," Irons said. "Because of the expansion of the universe, as we look farther away, objects appear more and more redshifted toward the IR range. For the first time, we have a telescope powerful enough to see very far away and also crucially look in the perfect region of the electromagnet spectrum."

Because the infrared light from the cosmological phenomena—which the JWST primarily explores—easily passes through dust, the telescope's sensors also let it see obscured objects historically undetected by its predecessors. As with the multiple mechanical upgrades, getting the JWST into orbit was an incredible feat of engineering, too—one that required precise planning.

"To prevent the telescope from glowing brightly in the infrared, it must remain very cold," Irons said. "To achieve this, it must be very far from Earth, which also glows brightly in the infrared. Thus, the telescope is currently orbiting L2, an unstable Lagrange point on the opposite side of Earth from the Sun about four times as far as the moon."

To get Webb to L2 (about one million miles away from Earth), NASA first launched the telescope aboard the Ariane 5 rocket. Shortly after it separated from the Ariane, the Webb used its onboard mini-thrusters to correct its trajectory toward L2. The JWST also performed many instrument checks and last-minute calibrations as it traveled to its final orbit.

All in all, the JWST has serious potential to greatly advance science as a whole. Within cosmology, scientists are hopeful that the telescope's improved and unprecedented abilities will advance humanity's understanding of stellar physics.

"An important area of research in cosmology is studying the first stars—specifically, how and when the first generation of stars was formed," Irons said. "We now have a telescope powerful enough to see these stars. The other 'hot' area of research is in discovering exoplanets—planets around other stars. The telescope's greater resolving power will help here too."

With the help of JWST's cutting-edge technologies, scientific progress is already being accelerated in these fields. The new technology will inevitably help humanity as it continues its journey toward becoming a space-faring civilization.

Story Vardhan Agnihotri
Graphic Michael Gao

Feature: ETHICS

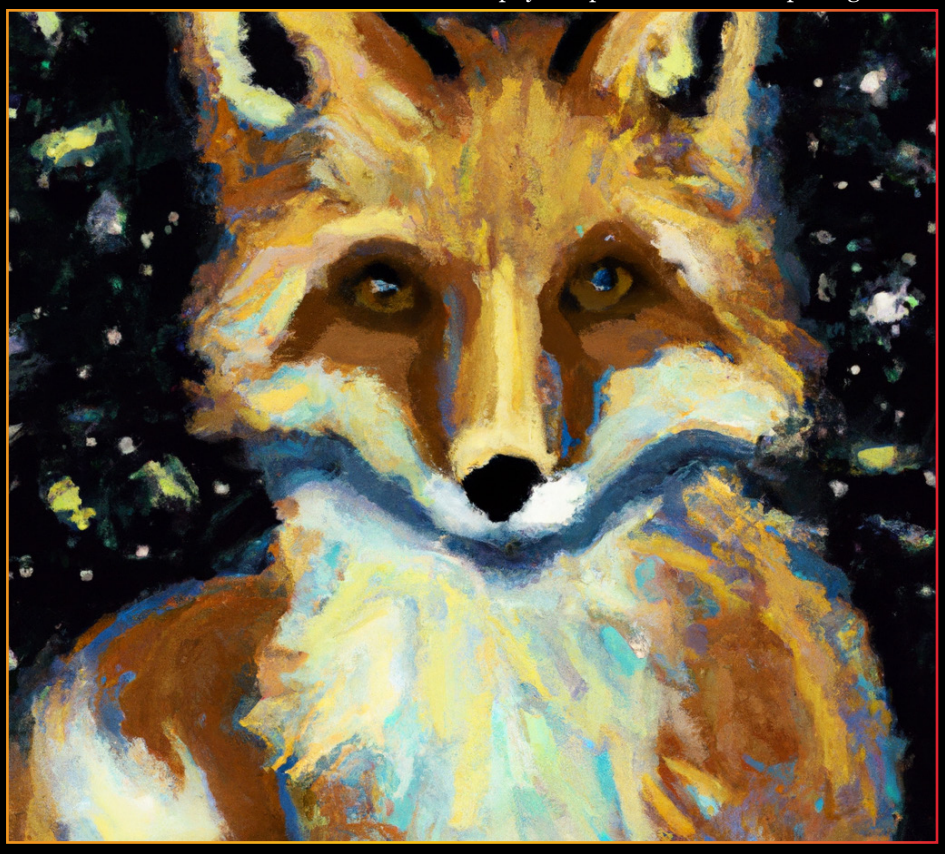
Ethics – the magazine's cover story. A play on "The Creation of Adam," Michaelangelo's famous Sistine Chapel fresco, this rendering of man and machine almost touching symbolizes the inevitable interweaving journeys of AI and its creator: us. The image and article also question AI's roles in society. As artificial intelligence advances and surpasses current technologies, how should it fit in societal domains like art? Should the art AI creates, with its intricacies and thought-provoking images, even be considered art in the first place? The answers to these questions will map out AI's role in the world and will determine its relationship with us for eons to come.

Ain't AI an Artist?

Does AI art deserve to even be considered art? What constitutes art in the first place? Does it matter where it comes from?

Monkey on the moon. Presidents playing poker. Six-footed centaurs.

More likely than not, within the past year, you've heard about AI art. Whether you're a tech-savvy artist, or a STEM-detesting high schooler, the past year has seen a boom in generative AI art, from dreamy fantasy landscapes to funky prompts like the above. It's even made its way into magazines like Cosmopolitan and Photo, along with taking prizes at photography competitions—like the prestigious Sony world photography awards this past April. But with AI art's rapid growth comes a crucial question for the world of art: Is AI art? And what would it take for AI to become recognized as art?



Prompt Given to DALLE2:
A painting of a fox in the style of Starry Night

Within the world of art, there's not much change in mediums. While artists and periods come and go, the core set of artistic mediums doesn't change as often. In fact, the most recent change happened a little over a century ago, with the introduction of photography. Like AI art, photography had a similar origin story.

"Photography was originally created by and for scientists," photography instructor Scott Hunt said. "It wasn't an art form at all. It was the pursuit of being able to capture an image. The first example of that was French scientist Joseph Nicéphore Niépce, who created an image overlooking a courtyard, using an asphalt-like material that hardened with exposure to sunlight. He basically took a box, put the material inside of it, and made an exposure that lasted all day long. The parts that hardened stayed, and the other parts he washed away. And that became the first ever photograph."

While the first photo was invented in 1827, its use cases were far more limited than the ones we know of today, with photography as an art form not discussed at all.

"People initially used photography from a reportage perspective, like Matthew Brady during the Civil War," Hunt said. "With the technology, they could reproduce images in newspapers and tell stories with pictures. It wasn't until the end of the 1800s that people started recognizing that we could use photography as an artistic medium too."

With that, photography started down its path toward its current role as another

artistic medium. The process, however, was still far from finished, and photography still didn't have a unique perspective on artmaking.

"In the late 1800s, there was a period called pictorialism when photography started becoming more artistic," Hunt said. "Photographers were manipulating images with cameras and the printing process, creating metaphorical and allegorical images that mimicked other art like Art Nouveau. Basically, photography was copying painting."

It wasn't until the early 20th century that photography decided to be its own art and capitalize on what photography could provide, slowly giving birth to pieces we consider photographic art today.

"That was when modernism was first established, and photography started becoming its own form of art," Hunt said. "For the first 100 years, photography wasn't considered an art; it was considered a science. Then it became a form of reportage, before finally becoming more creative towards the end of the 1800s."

Today, there's a little question that photography is an integral form of creative expression. But why exactly is that so? AI art has also been invented by scientists, and with similar artistic implications. Answering that question requires discussing what makes something "art" in the first place. The answer? Two key components.

> "In the late 1800s, there was a period called pictorialism when photography really started becoming more artistic. Photographers were manipulating images both with cameras and the printing process, creating metaphorical and allegorical-type images."

"In this day and age, I think art revolves around concept," Hunt said. "Just simply taking a picture doesn't necessarily make that picture 'art.' Making photos also involves intentionality, creativity, and decisions—but that's the next step. At its core, it has a concept, a 'why.' I always ask my students before every assignment: how do you intend to do it and why are you doing it? I think in this postmodern world of art, the 'why' in many aspects trumps the 'how.' With modernism, the 'how' actually mattered more in some respects, like having beautifully toned black-and-white prints that were critically sharp everywhere. But I would argue that our current postmodern era is more motivated by social factors."

In the case of postmodern photography, developing "why" comes in many different forms.

"Landscape photographers of the early 20th century sought to glorify the epic landscape, whereas 1970s landscape photographers were interested in showing man's impact on the environment, to make a social statement," Hunt said. "The same can be said for quite a bit of Contemporary Photography. What is the social statement? What is the impact? What is the motivation? It could be personal discovery or developing an aesthetic that has poetic and metaphorical qualities that can be read differently by different viewers. And thus, the viewer becomes part of the creative and collaborative process because they're interpreting and bringing their own life experiences to that image. It makes images something other than just something you look at, but rather something you engage with."

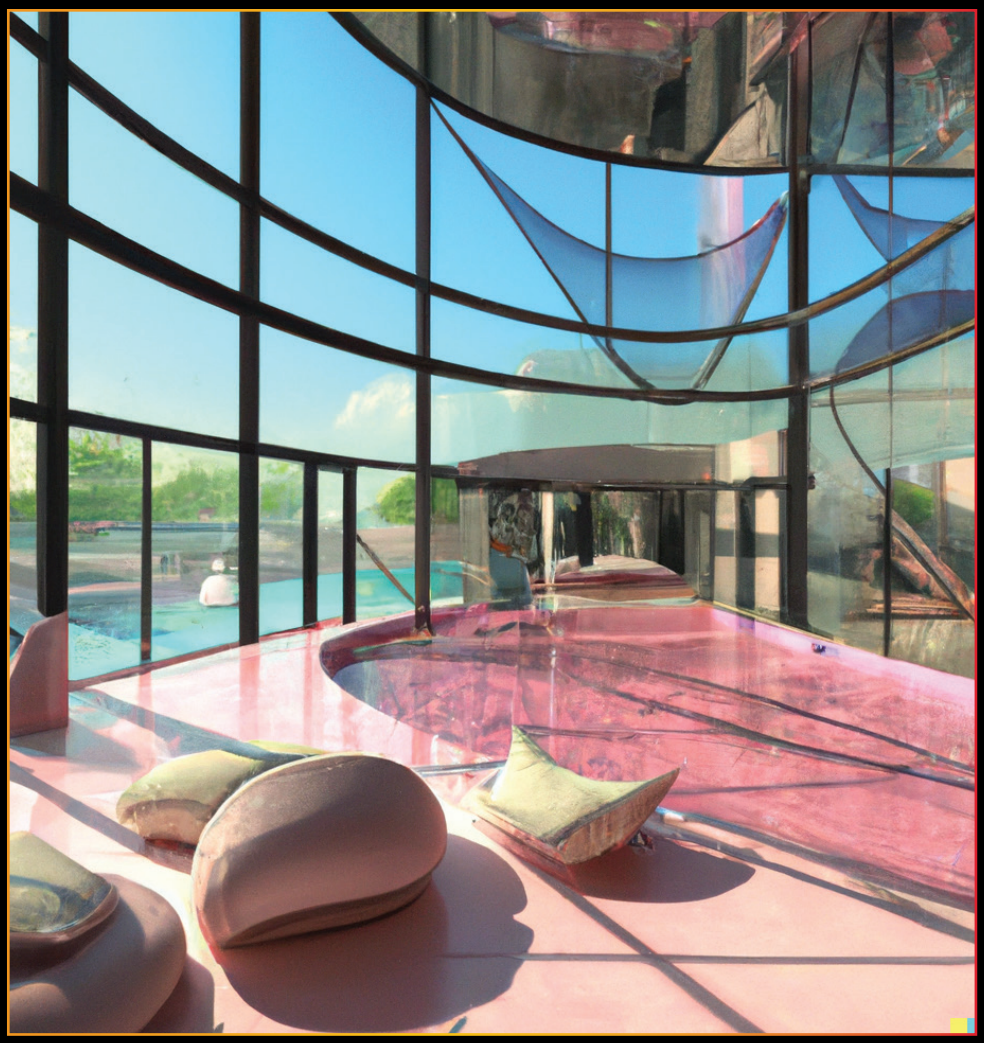
Judging under that standard, AI art isn't quite a formal art form yet, and most definitely is not the same as photography. However, like photography in its early stages, AI art may still have a road down to becoming art.

"I think it has potential to become art," Hunt said. "If somebody is writing and developing parameters that they're imagining in their head, and they use AI to turn that into an image which then they may manipulate do different things with—I think that can be thought of as art. But even though it looks photographic in nature and quality, I don't think it's photograph."

With that being said, even in its state today, artificial intelligence has impactful applications within the realm of art.

"What's fascinating to me as a photographer is AI software that allows us to do things we couldn't previously do," Hunt said. "For instance, there's this software package called Gigapixel which allows you to take an image made with an iPhone and resample and resize that image on a

*continued on next page



Prompt Given to DALLE2:
A sunlit indoor lounge area with a pool with clear water and another pool with translucent pastel pink water, next to a big window, digital art

Prompt Given to DALLE2:
An astronaut playing basketball with cats in space, digital art

Prompt Given to DALLE2:
An oil pastel drawing of an annoyed cat in a spaceship

Prompt Given to DALLE2:
A crayon drawing of several cute colorful monsters with ice cream cone bodies on dark blue paper

massive scale with minimal loss and image quality. We've all seen what happens when you blow up a photo too much and it loses sharpness. But I recently took a picture from my iPhone and manipulated it with the software and was able to print it eight feet by nine feet while still having amazing quality and sharpness. AI in that context allows us to improve what we can do. I already see AI technology benefiting photographers and the medium of photography in these ways."

The uses of AI goes beyond augmenting current forms of photography—it can even enable previously-impossible works of photography.

"There's a relatively new feature in Photoshop that's been around several years now called sky replacement," Hunt said. "It has a catalog of beautiful skies that you can go and drop into your picture to replace an ugly sky. The only problem is if your lighting direction and quality doesn't match your foreground, it looks fake."

In fact, as a photographer himself, Hunt foresees AI potentially replacing certain applications of photography as well.

"Something I find interesting is how AI art could negatively impact photography from a commercial standpoint," Hunt said. "You can see how advertisers might say, 'why hire a photographer when I can just provide a description to one of my creative directors?' It's not real, but it markets and sells. Given that so much advertising is happening online now, image quality doesn't always have to be as good either. It's a fascinating and groundbreaking time, and I do think AI art is a new medium."

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To sum up the current state of affairs with AI in art, its most impactful use case is still as a revolutionary tool to support other mediums. As AI-generated art develops, it is possible for it to join the ranks of photography and ceramics as new artistic mediums as well. But the path down that road is certain to contain philosophical questions about where the line for "art" will lie in the future.

"There's this piece about whether you're surrendering your creative decision-making to an automated system, as opposed to making those creative choices for yourself," Hunt said. "And does that somehow diminish the end product?"

Even with a well-established medium like artistic photography, debates continue today about the potential gray areas within photographic art.

"There's still this derogatory term today of 'oh, well, that's been photoshopped,'" Hunt said. "Somehow, if something had been photoshopped, in many people's mind that lessens the legitimacy of that image. And there's some people that still believe that today. Personally, I would argue that photoshop is different, but it's still photography. It still requires concept, idea, and mechanics, it's just a different tool."

As with key ethical questions surrounding journalistic photography—what you include in the frame, and how photos could manipulate perceptions of the "real thing"—AI-generated art also raises some interesting ethical questions.

"There's this photographer who's been making these beautiful portrait headshots of people with stories about each of them, and after a while, he revealed that they were all AI-generated, and the stories that went along with them were all fiction," Hunt said. "He allegedly did it to bring attention to the quality and the power of AI, and if you look at the images, they're great portraits. But these people don't exist. He's creating people that literally do not physically exist. And there's something kind of weird about that. I think it speaks to the power of AI, because these images seem purely photographic, and you're like 'Oh, that's a great picture of a person' but it's totally fiction."

In his role as a photographer, Hunt has concrete answers about the boundary between AI and photography. But as for the boundary between AI and art, the lines are still unclear.

"At the end of the day, when we're creating art, I think less about what we do as photography, and more as image creation," Hunt said. "And that then kind of goes back to the question, is AI art? It could be because it's image creation. It's not photography, because it's not using a camera or using any of the technical requirements, but it is creating imagery.

If there is anything conclusive Hunt can draw about the sea of uncertainty surrounding AI art, it's that its journey will be its own, on a separate path from photography.

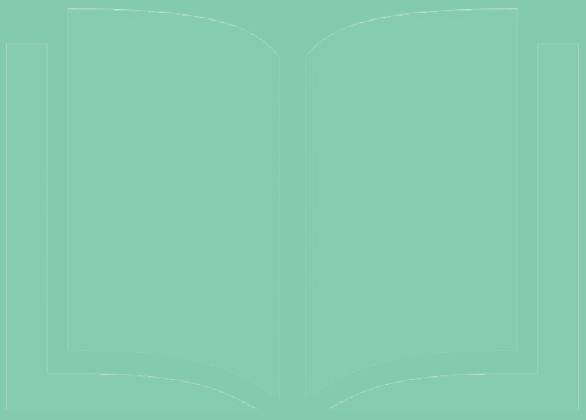
"With AI, I see it as just a completely different medium," Hunt said. "Maybe now I sound like the people complaining about photography 20 years ago, but I just don't think it involves creativity yet. It definitely does have the potential for creative image making—and it might be used for that in the future. But at the end of the day, I don't think it's photography, and it's definitely its own, separate medium."

Story Aaron Liu
Graphics DALLE2

Prompt Given to DALLE2:
A photo of Michelangelo's sculpture of David wearing headphones djing

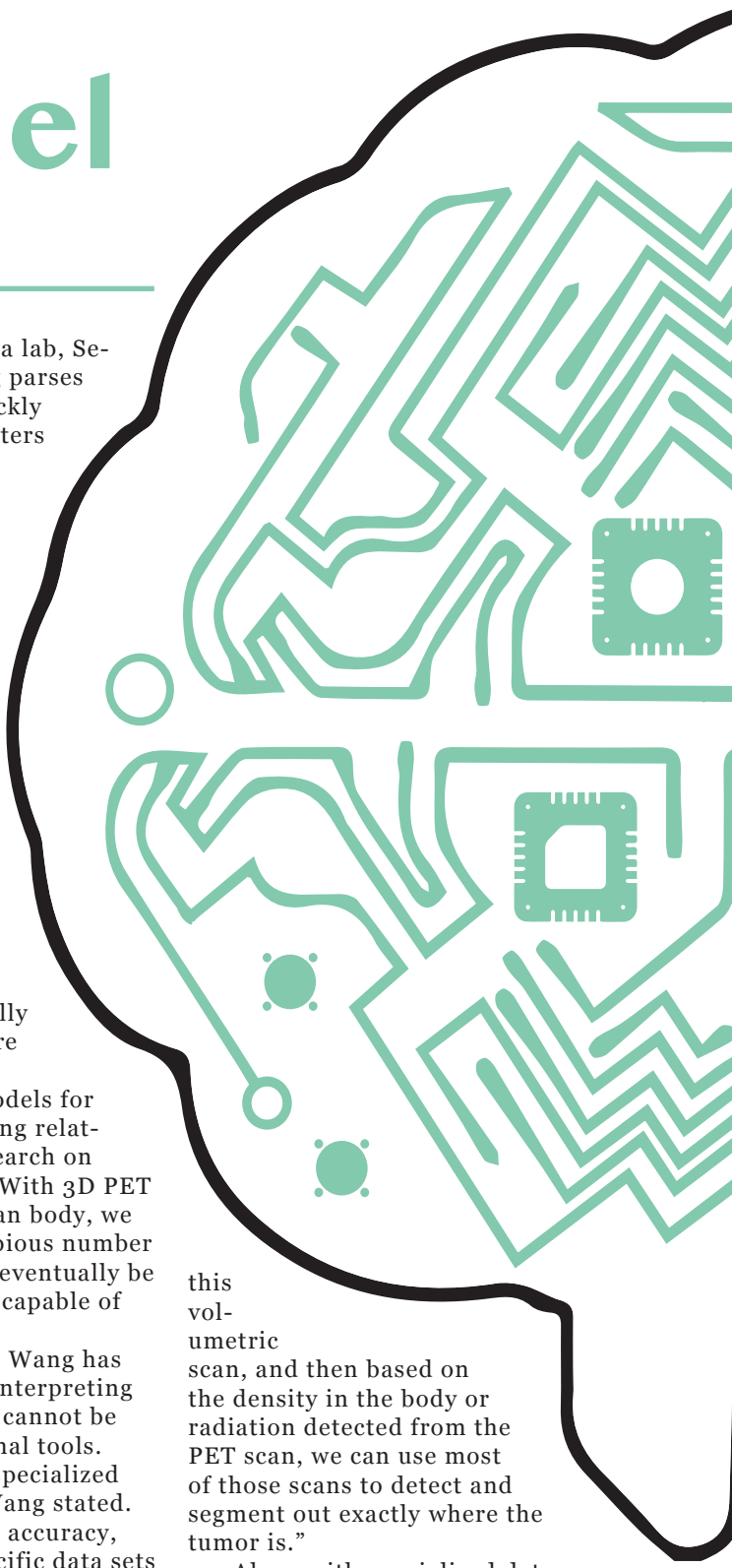
Section II: TRAINING

Training is characterized by interpreting and learning from data through constant trial and error. Whether it's through daily school classes, grueling sports practice, or something as simple as getting up in the morning, our lives are all governed and strengthened by training. This section of the Scientific Marksman describes the "training" that St. Mark's students undergo to take their first steps into the professional fields that they are passionate about. Only through proper "training" and inspiration from teachers and mentors can students succeed in projects and undertakings. In this section, we discuss various global issues (like the world's water crisis) that students have taken notice of and are currently "training" to solve in the future. Through fostering deep curiosity and interest in specific world issues, students will be well-prepared to tackle various challenges and improve humanity's trajectory into the future. "AI Training," this section's capstone story, explores AI learning and how it trains to self-improve. Whether tackling Dallas's water crisis, creating underwater robots, or kickstarting a whole scientific magazine, training provides us the foundation to reach for the stars.



Training the AI Mind Model

Using a variety of methods to train AI, senior Anthony Wang was able to successfully train a model to parse 3D PET and CT scans and identify cancer tumors.



Working tirelessly in a lab, Senior Anthony Wang parses thousands of photos, quickly identifying potential clusters of tumors, teaching, and training something that will eventually replace him: an algorithm, or rather, artificial intelligence.

Wang is not the only one seeking to train artificial intelligence. As the industry grows, more and more large tech companies have been investing in specialized AI, such as OpenAI's renowned chatbot, ChatGPT. These investments have paid off, as they have led to several breakthroughs in AI technology, especially in the medical field, where Wang experimented.

"I have worked on models for biomedical imaging," Wang related. "I have also done research on tumorous segmentation. With 3D PET and CT scans of the human body, we are able to generate a copious number of 3D models, which can eventually be used to create AI models capable of detecting tumors."

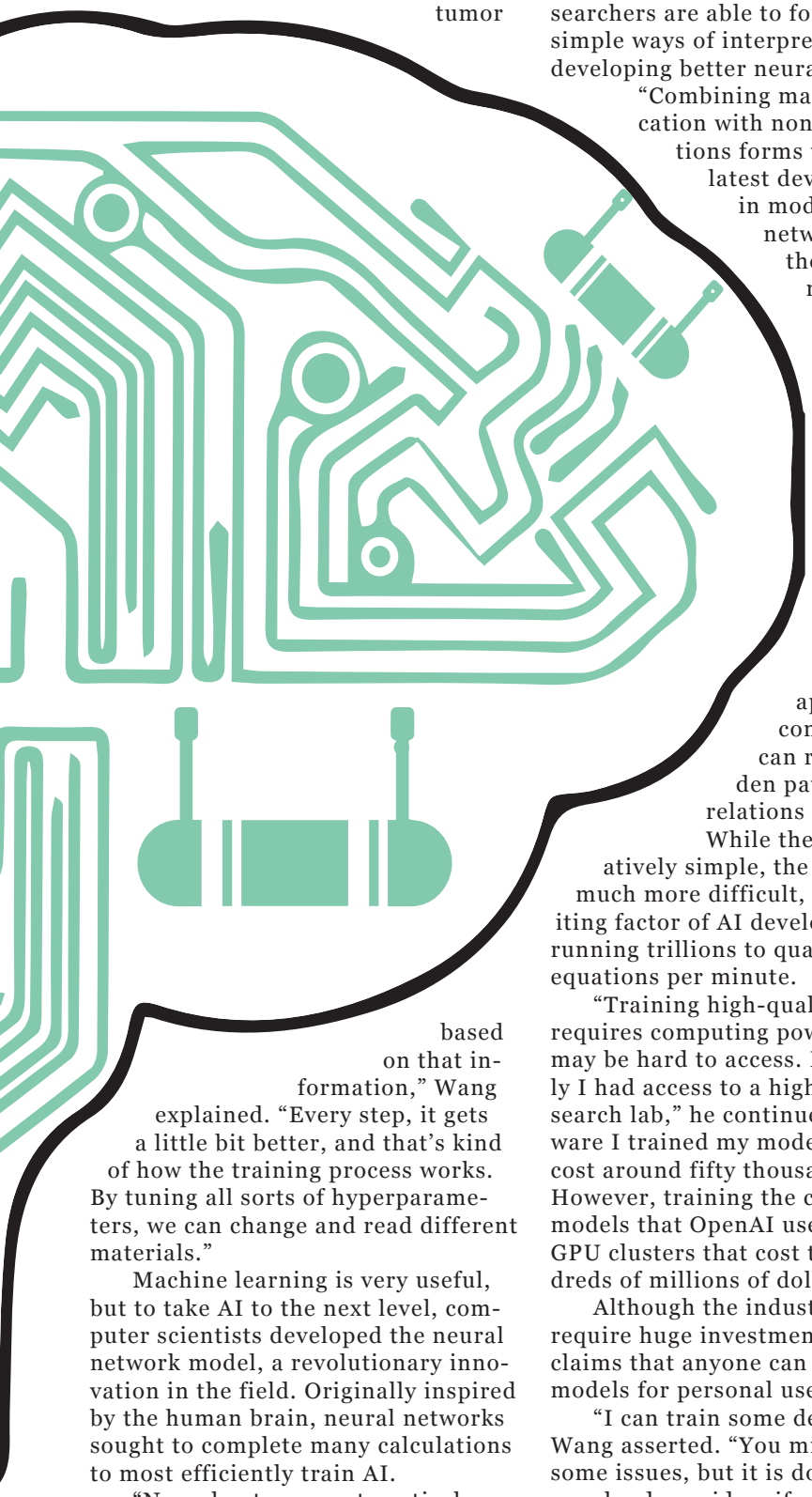
One of the challenges Wang has faced is the difficulty of interpreting these 3D models, as they cannot be interpreted with traditional tools.

"This requires more specialized datasets than normal," Wang stated. "In order to achieve peak accuracy, we need to have very specific data sets for biomedical imaging. We feed in this volumetric scan, and then based on the density in the body or radiation detected from the PET scan, we can use most of those scans to detect and segment out exactly where the tumor is."

Along with specialized data-

sets, Wang used a method called machine learning to enable his model to identify whether a patient has a tumor or not, information that is critical for early diagnosis and prevention of cancer.

"Machine learning looks at many different previous instances and tries to detect the tumor based on that information," Wang explained. "Every step, it gets a little bit better, and that's kind of how the training process works. By tuning all sorts of hyperparameters, we can change and read different materials."



Machine learning is very useful, but to take AI to the next level, computer scientists developed the neural network model, a revolutionary innovation in the field. Originally inspired by the human brain, neural networks sought to complete many calculations to most efficiently train AI.

"Neural nets are systematically built off the machine learning training process, with an addition of gradient descent, automatic differentiation, and backpropagation," Wang explained. "Neural nets use math to teach neural networks to learn data transformations."

With increasingly advanced technology and GPUs (Graphic Processing Units) being developed, more researchers are able to formulate new, simple ways of interpreting data and developing better neural networks.

"Combining matrix multiplication with nonlinear functions forms the core of the latest developments in modern neural networks. Some of the most famous models, like ChatGPT, are really just built from a combination of matrix multiplication and nonlinear functions," Wang revealed. "Just by repeatedly applying those concepts, they can recognize hidden patterns and correlations in raw data."

While the idea is relatively simple, the execution is much more difficult, for the limiting factor of AI development is running trillions to quadrillions of equations per minute.

"Training high-quality models requires computing power, and GPUs may be hard to access. But fortunately I had access to a high-quality research lab," he continued. "The hardware I trained my models on probably cost around fifty thousand dollars. However, training the competitive models that OpenAI uses would need GPU clusters that cost tens or hundreds of millions of dollars."

Although the industry models require huge investments, Wang still claims that anyone can train usable models for personal use.

"I can train some decent models," Wang asserted. "You might run into some issues, but it is doable. There are cloud providers if you want to train a language model or image recognition model. In theory, anyone can sit down and calculate keys by hand."

Despite his assertion, Wang realizes that there are difficulties in training and implementing an AI, especially with regards to understanding the conceptual basis behind the models.

"It used to be classical computing, where you learnt the algorithm, and you understood exactly what the algorithm was doing," Wang said. "Classic computing is very explainable, whereas in machine learning, you give it a bunch of data and you fit the model to the data. It then replicates the data, and transformation of data to what you want it to do, but you don't know how it's doing it."

Since the start of computing, training like this has been theorized and even tried before. But due to the lack of technology, previous generations only generated average models.

"I would say one of the biggest factors in successful training is the advent of GPUs and highly powerful computers," Wang shared. "Because of resource-intensive algorithms like back propagation, it is only possible with modern computers. Modern machine learning was actually invented in the 1980s, but it was not successful until around 2010, for that was when our computers started getting fast and powerful enough to handle AI training."

Because of better computers, researchers can train these models with significantly larger amounts of data, a vital step in increasing AI effectiveness.

"By taking advantage of the best computers, these models started to get better, and they continue to show promise," Wang continued. "At the kind of scale our GPUs are getting faster at, there will be a huge increase in performance in the next few years. As we can see, we already have models as powerful as ChatGPT. More models like these will continue to appear thanks to the larger amounts of training data provided by the processing power of these new computers."

Story Joseph Sun
Graphic Michael Gao

The STEM Conference of the Decade

2023 marks the tenth anniversary of the student-led STEM conference. Guests Andrew Gatherer, Stacy Pritt and Sara Ord gathered both to explain their research but also discuss the ethics in STEM.

The 10th anniversary of the annual student-run STEM Conference occurred on March 4th, 2023, and brought together students, professionals, and experts across various fields of science, technology, engineering, and mathematics. The conference, held entirely on campus, featured a large panel discussion and classwide lectures throughout the day, all focused on the revolving theme of "Ethics in STEM."

When asked why ethics was chosen as the theme for the conference, Will Grable '23, STEM Conference co-chair, remarked, "We wanted to find something that was able to bring together everyone in the audience, whether they had a passion for STEM or not. Ethics is relevant in everyone's life and affects everyday decision-making, so we thought it would be a good conversation starter that allowed the experts to delve into the ethical applications of their fields, many of which don't really get mentioned often."

Return of the King
Andrew Gatherer '14, the creator of the STEM conference, now returns to enthrall the Upper School with his tales of SpaceX and satellites.

The conference was headlined by Dr. Stacy Pritt, the Associate Vice President of Research Support and Regulatory Management at UT Southwestern, Ms. Sara Ord, the Director of Species Restoration at Colossal, and Andrew Gatherer '14, a Guidance Navigation and Control engineer at SpaceX.

Dr. Stacy Pritt, an animal researcher at UT Southwestern, is responsible for administering the conflict of interest, institutional animal care and use committee, and stem cell research oversight for one of the largest biomedical research universities in the United States. At the 2023 STEM Conference, Dr. Pritt gave fascinating remarks about the importance of animal research in advancing human health and medicine.

Dr. Pritt's classroom lectures involved her explaining the history of ethical frameworks in animal research and how they compare to each other. She discussed the strict guidelines and regulations that must be followed to ensure the safety and well-being of the animals involved.

Despite its ethical implications, Dr. Pritt emphasized the importance of animal research in advancing human health and medicine. She highlighted the many breakthroughs that have been made possible through animal research, such as the development of vaccines, treatments for diseases like cancer and diabetes, and the understanding of fundamental biological processes that underlie human health.

One of the highlights of the conference was the lecture on species de-extinction, led by Ms. Sara Ord, the Director of Species Restoration at Colossal. Colossal is a relatively new Dallas-based company that has gained half a billion dollars in funding since it was founded in 2021. Ms. Ord was the very first employee hired and joined after completing her Master's Degree in chemical and biomolecular engineering at Johns Hopkins University.

Currently, Colossal is working to bring back two extinct species, the Wooly mammoth and the Tasmanian Tiger. Ms. Ord said that the de-extinction of these species could provide an opportunity to restore ecosystems that have been disrupted by human activity. For reference, Ms. Ord used the example of the reintroduction of wolves into Yellowstone National Park in the 1990s, an effort which had a profound impact on the park's ecosystem and led to increased biodiversity and a more balanced predator-prey dynamic.

On the other hand, Ms. Ord also discussed the potential risks associated with de-extinction. One of the primary concerns is the impact that reintroducing extinct species could have on existing ecosystems. For example, the reintroduction of a predator into an ecosystem that has been predator-free for centuries could have unintended consequences, such as a decline in the population of other species. Additionally, there is the risk of genetic diversity being lost due to the small population size of the recreated species, which could lead to a lack of adaptability to changing environmental conditions.

She also discussed the ethical considerations involved with de-extinction and mentioned how critics argue that de-extinction could divert resources from more pressing conservation efforts, such as preserving the habitats of endangered species. Additionally, she mentioned concerns about the welfare of the recreated animals, including their ability to adapt to their new environment and the potential for suffering during the de-extinction process.

The final guest for the 2023 STEM Conference was Andrew Gatherer '14. Renil Gupta '23, a STEM Conference co-chair who invited Gatherer, commented, "It was very special to be able to invite Mr. Gatherer back to the STEM Conference. He was the one who founded the STEM Conference at this school ten years ago, so I thought it would be only appropriate to bring him back for the 10th anniversary."

Mr. Gatherer is a Guidance, Navigation, and Control engineer at SpaceX, and he works almost exclusively on Starlink, a satellite internet constellation that provides internet around the globe. Mr. Gatherer gave an illuminating talk on the development and implementation of the Starlink satellite network, as well as the potential benefits it could provide to people all over the world.

Gatherer explained that the network consists of thousands of small satellites placed in low Earth orbit. These satellites are designed to communicate with ground-based terminals that provide internet access to users. The network has the potential to revolutionize the way people access the Internet, particularly in areas where traditional infrastructure is unavailable or unreliable.

His talk also raised important ethical considerations related to the use of satellite technology, and he explained different ethical positions that could be taken in certain scenarios. For example, one of the key ethical concerns related to the Starlink network is the potential for the satellites to contribute to space debris. As Gatherer explains, while the satellites are designed to eventually deorbit and burn up in the Earth's atmosphere, there is still a risk that they could collide with other satellites or objects in space and create more debris. This could have serious consequences for future space exploration and could even pose a risk to human life. The two extremes are limiting all satellite technology or not worrying about space debris at all. He went on to describe SpaceX's middle-ground stance in trying to minimize any waste while still producing satellites.

Overall, the conference was a great success, raising important ethical considerations related to STEM fields and encouraging students to think about the impact of their work on society.

Story Kevin Lu
Photos Michael Gao

Blast From the Past
Dr. Sara Ord talks about Colossal's goal in resurrecting the Wooly mammoth and the Tasmanian Tiger through stem cells.

A Deep Dive into the Ocean with Robots

To explore the Mariana Trench and to know what lies in 75% of the Earth, Harry has resolved to designing spider robots.

Junior Harry Wang always had a strong curiosity about the ocean. While it started small—frequenting beaches on vacation—throughout the past few years, it's fused with his interest in science, cumulating in one question: what lies beneath the surface, in the murky depths below? When reading online articles left him unsatisfied, Wang decided to take matters into his own hands and change the status quo: that we've yet to explore 80% of the ocean.

He started by researching ways to explore the ocean better, leading him to aquatic robots. But traditional robots are made of hard materials, such as plastics and metals, and they struggle under the massive pressure conditions in the deep, unexplored ocean depths. Instead, Wang decided to look into soft robots.

"For the most part, soft robots are like traditional hard robots, but instead of hard metals, they're made up of silicone and other soft materials," Wang said. "This makes them more pliable and flexible in their movement. Regarding ocean exploration specifically, soft robots have advantages like higher resistance to temperature, pressure and unexpected factors that come with ocean exploration, which hard robots don't provide."

While the adaptability of soft robots made them an attractive choice for exploration-based tasks, after a bit of research, Wang realized a few tradeoffs with the technology as well.

"Right now, soft robot ocean exploration is pretty limited because currently deployed ones are swimming-based, meaning they can't collect data from the bottom of the ocean. This makes it easy to miss out on information regarding plants, deep-dwelling animals and plate tectonics—information that's crucial to marine archeologists, environmental scientists, marine biologists and other scientists in the field."

"Right now, soft robot ocean exploration is pretty limited because currently deployed ones are swimming-based, meaning they can't collect data from the bottom of the ocean, missing out on information regarding plants, deep-dwelling animals and plate tectonics."

In response, Wang started researching the idea of a walking-based soft robot. His primary tasks were experimenting with soft robot components, testing the effectiveness of different "walking" movements and determining the best movement patterns and physical components.

"The main goal behind my research was to engineer a leg design paired with a method of movement that could resist intense temperatures and remain flexible and strong," Wang said.

To decide what method of movement to use, Harry took inspiration from biology: the spider.

"Spiders are very versatile movers that use very little energy and yet exert a lot of force and move quickly," Wang said. "I wanted to copy the arachnids' efficiency, so I created designs of legs that would mimic spider movement by flexing inward, creating a rearward force that propels the robot forward through the water."

Harry used computer-aided design (CAD), his favorite part of the process, to design each leg model's mold. In the end, he settled on three different types of models, each of which he tested extensively to determine the proper proportions. The key differences between the models revolved

around the positioning and number of studs on the leg. The studs served to simulate the spider-like motion he was trying to imitate. But after laser-printing molds for each model, Wang encountered his biggest challenge: to make homemade silicone to put into the molds.

"Making my own silicone was really difficult because there were always some air bubbles in the silicone, which meant that the final molded leg would have imperfections that leaked air," Wang said. "In a real future underwater robot, that could cause major problems."

Only after testing multiple different silicone mixes did Wang correct the air bubble problem, which brought him to the final stage of his experiment: data collection. To measure the effectiveness of each of his designs, Wang measured how much each leg increased in height in proportion to the amount of pressure put on it—in other words, a measure of the leg's flexibility.

"To mimic the movement the legs would have to perform, I manipulated a wire connected to the leg," Wang said, "and observed the effect of air pressure on performance as well. The wire gave me data on how pressure affected the legs, depending on the stud count and placement."

After analyzing the collected data, Wang found that the more studs a leg has, the more sensitive it is to changes in air pressure. That would translate to a higher load limit in the real world, offering more application versatility. This principal finding, along with the additional details he observed in the design, led Wang to his final, optimal design.

"In the end, I determined that the single-sided 9-studded model at 23 PSI worked the best for aquatic movement," Wang said. "Given its applications in both aquatic and space exploration, I wrote a comprehensive paper summarizing the main points of my work, which I entered into the Junior Science and Humanities Symposium competition."

In the future, Wang plans to improve his project into a practical and deployable solution.

"I want to develop the movement system and the internal pressure system, as well as test the prototype once I get the chance," Wang said.

Looking back on his work throughout the past year, Wang has two messages he finds essential in the scientific process. Firstly, about methodology.

"If anyone's looking to work on science projects in the future, I'd recommend working on the experiment with a professor," Wang said. "I did all the research and experimentation on my own, but if I could do it again, I would want to do it with a professor. It would be much easier to tackle the more technical problems of the design process that often require experience to solve."

And finally, about the field—one in which he hopes to continue to work in.

"I'd encourage more people to work on solving problems with ocean exploration," Wang said, "because ocean exploration is very valuable. We can learn about animals, look into the mechanics behind tectonic plates, and overall just better understand questions relating to sustainability and natural disasters."

Story Arnav Lahoti
Graphic Michael Gao

First Tech Challenge Robot
Working with the school's robotics team, Anthony Wang engineered a robot that can efficiently grab and drop cones.

Reinventing Robotics

Senior Anthony Wang is part of a world class robotics team, which uses cutting edge technology and industry level software to create fascinating machines.

In a world where technology is rapidly advancing, high school robotics programs are nurturing the future generation of innovators. Young highschoolers from robotics teams all over the world create faster, simpler, smarter solutions to any puzzle thrown at them. Over the course of many months, these students must perfect their unique solution to the problems proposed by robotics organizations. The clinks of metal and flurry of keystrokes fills many labs across the globe as students feverishly work to perfect their creations. Long nights, early mornings, in the end, the rush of excitement at the competitions makes it all worth it. These young engineers bring their designs to life, observing their little creation whirring on competition floor. Senior Anthony Wang is one of these many young men immersed in the world of robotics. From starting as a novice coder back in middle school, to becoming a leader of an international level robotics team, Anthony provides his unique perspective on the world of robotics.

One of the major competitions for robotics is the FIRST Tech Challenge (FTC). For grades 7-12, students create robots to compete against other teams in a head to head format. Anthony's team frequently attends this competition, and he talks about his teams most recent performance.

Anthony said, "We performed pretty well. I was only there for half of the day, but my teammates did well. We ended up as the first seed and ended up winning the Inspire Award, the overall judging award."

Though the FTC may seem straightforward, the competition structure of robotics can be difficult to understand. Anthony elaborates further on the complexity and intricacies of the FTC competition.

"There's a red alliance and a blue alliance, and you have two teams on each Alliance," Anthony explained. "These teams try to score cones to gain points for their own side. There's an autonomous period where the robot drives itself and there's a manual period where the robot is controlled by human drivers. In the autonomous period, you get more points for stacking cones on these poles. There are around ten poles around the field, and you get more points for putting the cones on the poles. So the game is essentially about stacking cones on top of poles."

While the team performed very well in the competitions, Anthony said that their performance was not flawless and that there were a couple challenges that they faced at the tournament, such as "inconsistent autonomous performance, which means that during the autonomous period, the robot

just missed the poles because there were some issues with our robot's self-localization . . . sometimes we encountered issues with that, so we didn't score all five cones that we could have."

The robotics team's success at this tournament will open doors to the other levels of the competition.

As Anthony describes it, as of February, "we have potentially three more tournaments. We have regionals, states, and worlds. And I guess our plan is to go directly from regionals to worlds by getting the Inspire First award. And, at the moment, we plan to keep our robot the same and just make it more consistent, but if we qualify for states or worlds, we could consider redesigning the robot."

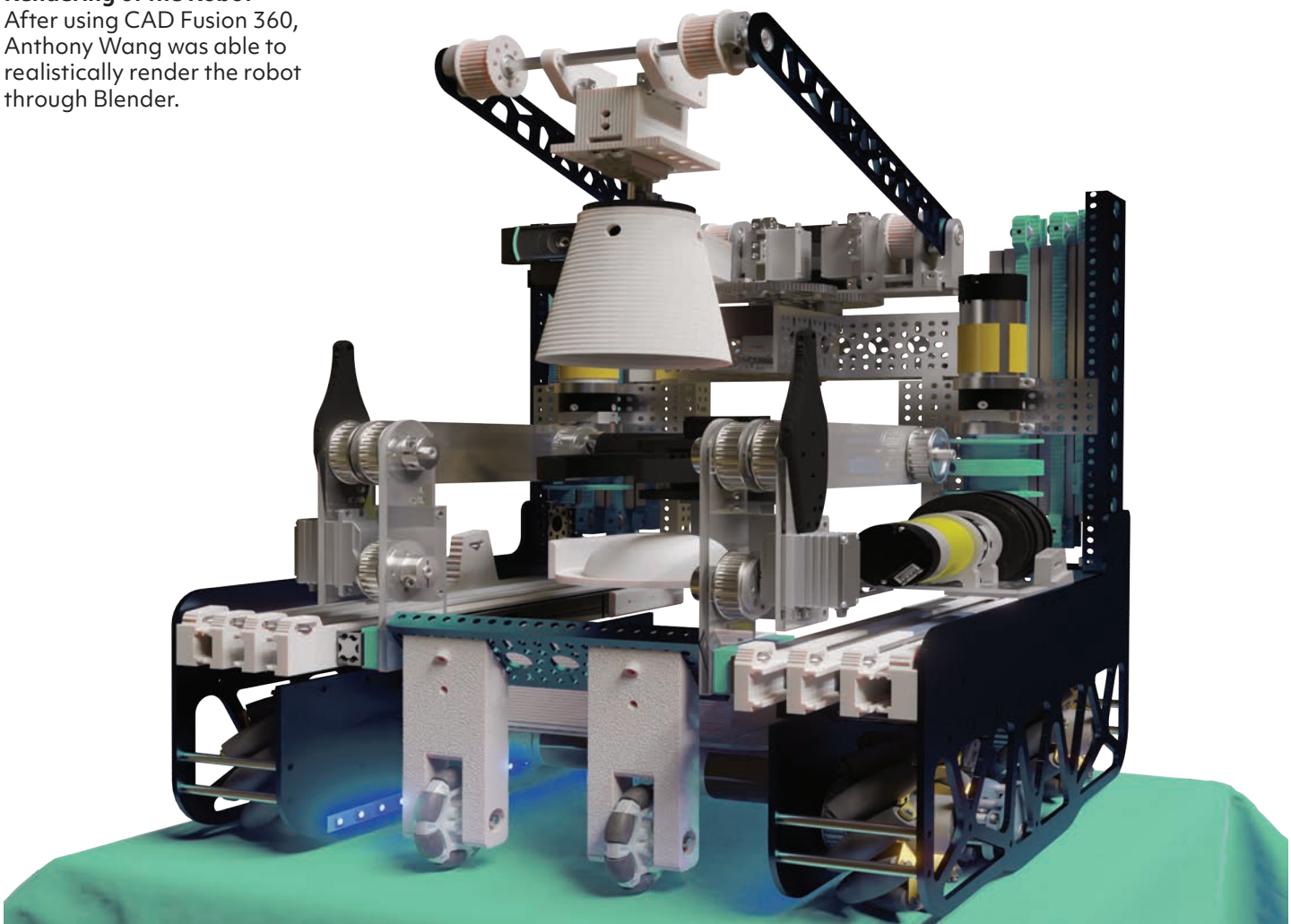
Since the first round of tournaments, the robotics team has been perfecting their design, skipping the state tournament and going directly to the world tournament.

The skills learned through robotics can be precious assets going into college and life in general. The St. Mark's robotics team is a fantastic example of how students can foster problem-solving, perseverance and cooperation through hard work and determination.

"So I've done FIRST robotics for 12 years now, and I have really liked the fact that it's taught me how to become a better speaker and presenter," Anthony recounted as he explained personal benefits he has derived from participating in his robotics league. "Learning how to present to judges and explain your robot to other people is an essential life skill that goes way beyond robotics and is applicable to almost anything. Within the robotics game itself, I like the fact that there is almost endless potential for experimentation. You can play around with a lot of different software libraries and building and manufacturing techniques. So, I like FTC because it's relatively open-ended. You can 3D Print things, use CNC (Computer Numerical Control), design your robot completely in CAD (computer-aided design), meaning there's a lot of room for exploration and creativity in that area."

Story Griffin Goodno
Photos Joseph Sun

Rendering of the Robot
After using CAD Fusion 360, Anthony Wang was able to realistically render the robot through Blender.



Back to Square One

Alex Rothkrug '12, the first Editor-In-Chief of *The Scientific Marksman*, describes what the magazine was like back then and how he feels about how far it has come now.

How'd you get into SciMark, and how long did you work on it?

Rothkrug: I was the club's founder, and I was the editor-in-chief from my first year, I think in 2010, during my sophomore year.

What inspired you to start the whole SciMark publication?

Rothkrug: Yeah, I was kind of the 'Science Guy' throughout high school. I liked reading Scientific American and I was really into things like that, which is where I came up with the publication's name—a Scientific American right here on campus. I also kind of knew I wanted to do something in biology or medicine in college, and that was part of my inspiration for starting it. And then one other thing I realized was that St. Mark's has like a lot of resources when it comes to student publications—we already had The ReMarker winning awards every single year, so I figured, you know, if we had another science-focused publication, we could probably achieve the same level of excellence too. Just given my situation, with my ideas and the resources available, I thought it'd be a good way to get people involved and spread some science news around campus.

What was the process, going from your initial idea to gathering your first full staff?

Rothkrug: The majority of my part was first piecing together a team of people and then figuring out what I was able to do myself and what I wasn't able to do. The parts I liked most were researching for articles, writing articles, editing articles, stuff like that. But designing layouts—that was something that I didn't really have much experience in. I taught myself a little bit of InDesign and PhotoShop at the time just to learn the basics, and then I started consulting people from the ReMarker and other publications, just having them look over pages and help out. I think I ended up having someone from the ReMarker as our layout editor as well. Another big thing was that we had a lot of support from faculty and staff at the time. The Head of the Science Department was Mrs. Barta, and Dr. Perryman was one of the deans and they were both really helpful advisors. We also had people from the Alumni Office help with coordinating with the printing company and the whole process printing process. It really was a team effort at the end of the day and recognizing who has the skills that you need to execute which task.

What were some challenges you faced while leading SciMark?

Rothkrug: My first year, being a sophomore, it was hard to step into a leadership role and expect people to go along with your idea. I wanted to retain the Editor-in-chief role since it was my concept, so I looked to seniors who were leading other clubs, like the Biology Club and the Chemistry Club, and had them join the founding team with me. Then, they were able to recruit people that may not have initially wanted to join but were now open to joining since they saw that we had a good team in front of this thing.

What were your favorite parts about working on SciMark?

Rothkrug: One of my favorite parts was being able to read stuff that my classmates wrote. The first few years, some people would submit research papers from their summer research, and I got to see some of the stuff my peers were working on. Another good memory was when I got to talk with Spencer Wells, who's a famous geneticist that worked with National Geographic. We had a school assembly that day, and after his presentation I got to interview him for a magazine story too—and I think when my brother led SciMark he got the opportunity to interview Mark Cuban. It's just cool having access to people that are very kind of prominent in the STEM space, and getting those opportunities to talk to them, to hear their insights into certain topics. So I would say just a combination of reading pieces people submitted and being able to enjoy interviewing people in the field.

It's been a while since you stepped back from leading SciMark. So what are you working on now?

Rothkrug: Right now, I'm just finishing up residency. I finish my anesthesia residency in July, so after that I'll start working toward being an anesthesiologist. I'm looking to go on to Pain Medicine Fellowship at UNC for the following year, and then after that, look for my first attending job.

Would you say your time on SciMark influenced anything in your career path, or life after St. Mark's?

Rothkrug: I would say it definitely reinforced by decisions. I always had an idea that I wanted to do something in science or medicine, and SciMark really just reinforced that. Also, the whole process of learning to write and edit scientific articles, that also carried over and helped me when it came to doing research for medical school and residency, writing presentations, things like that. Everything kind of came together because I already had that literary experience.

What were your main thoughts wrapping up your last year?

Rothkrug: My biggest fear about SciMark was that it would just die out after I left. I wasn't sure if there would be enough interest to keep it going; I didn't know if it was just me keeping the fire lit, or people were still going to be interested. I'm really happy that it's still going strong now.

Interview Aaron Liu
Photos Courtesy of Rothkrug

Poison from the Pipes

America was known for its clean water. Unlike most countries, drinking from the tap was normal and completely healthy. But with lead contamination, this long tradition might just be over.

Water supply exposed to lead poisoning. Thousands suffering from water contamination. Hundreds of children sick. Over the past decade, headlines like these have become concerningly common throughout the United States. From Flint, Michigan's lead contamination crisis, to Austin, Texas's infrastructural issues, each of these crises has threatened thousands of lives. With so many critical problems around us, we can't help but raise the troubling question: will we also have similar issues with water contamination? As a community of Dallasites, we need to understand how the city of Dallas treats its water to bring a sense of security among citizens and raise awareness for potential future issues.

DWU, or Dallas Water Utilities, is the company that supplies Dallas with high-quality, fresh, clean water every day. Denis Qualls and Alicia Lee are significant leaders of DWU, with Denis being the superintendent of DWU for almost twenty years and Alicia Lee leading conservation efforts for the company. They ensure that Dallas is doing a great job providing safe and clean water to its residents and provide critical information for Dallas residents to know.

Dallas's water treatment process consists of settling, filtering and ozone disinfection. The first step involves "settling" or the removal of suspended solids. DWU uses lime and iron sulfate, which helps with corrosion control. Once the solids are removed, the water undergoes gravel and sand filtration.

Once all the unwanted contaminants are removed, DWU moves on to the next stage: disinfection. DWU relies on specially chosen chemicals in this stage to maximize water safety. First, chloramine (a compound of chlorine + ammonia) was chosen for disinfection and consumer safety (since chloramine is less toxic than chlorine). Then, ozone, a powerful oxidizing agent which releases a broad-spectrum biocide, is used to kill diseases, viruses, bacteria and cysts. Afterward, fluoride, a substance that reduces tooth decay when added to water sources, is added. Additionally, activated carbon is used to control the taste and odor of the water.

Currently, Dallas's water is considered a "Superior" water system, which is the highest award for water quality given by the State of Texas. Dallas' water also meets or exceeds all requirements and recommendations given by the state and federal government as well as the EPA, reflecting the extensive care that DWU uses to treat our water supply.

Dallas Water Utilities' website outlines the positive effects of their treatment process, stating that "the combination of our treatment processes and the non-corrosive nature of Dallas water results in exceptionally high quality, safe drinking water." In 1991, DWU won the Environmental Protection Agency's Region 6 Environmental Excellence Award for Public Water Supply. That means that Dallasites are drinking some of the best water in five states: Texas, Arkansas, Oklahoma, Louisiana and New Mexico."

DWU tests Dallas' water around 45,000 times per month or almost 63 times per minute. These tests must meet all the testing requirements set by the FDA – the city also exceeds these requirements by performing extra tests for other toxins and chemicals not on the FDA's list – this specificity has contributed to the pristine water supplied to the city.

Though Dallas has a highly well-managed system, there are still some risks that could threaten the water supply in the future.

For example, most of Dallas' infrastructure is over 30 years old. Despite continuous efforts to maintain, repair and replace various facilities, it is unclear whether there is a sufficient budget to sustain this infrastructure and whether the pace of repairs and upgrades will be able to stave off future issues.

As Dallas continues constructing more infrastructure, especially as projects like the Integrated Pipeline Project, a new water supply project, are being completed, the operating budget must increase to cover

new maintenance costs. It still needs to be determined how much the budget is slated to increase.

As the climate continues to warm, so does evaporation, which would decrease the Dallas water supply. Factors such as rainfall could also fall, making the current climate's effects on the water supply unclear. Furthermore, as experts discover more information about new and existing chemicals currently used to treat water, scientists could find unknown harmful effects of these chemicals on humans.

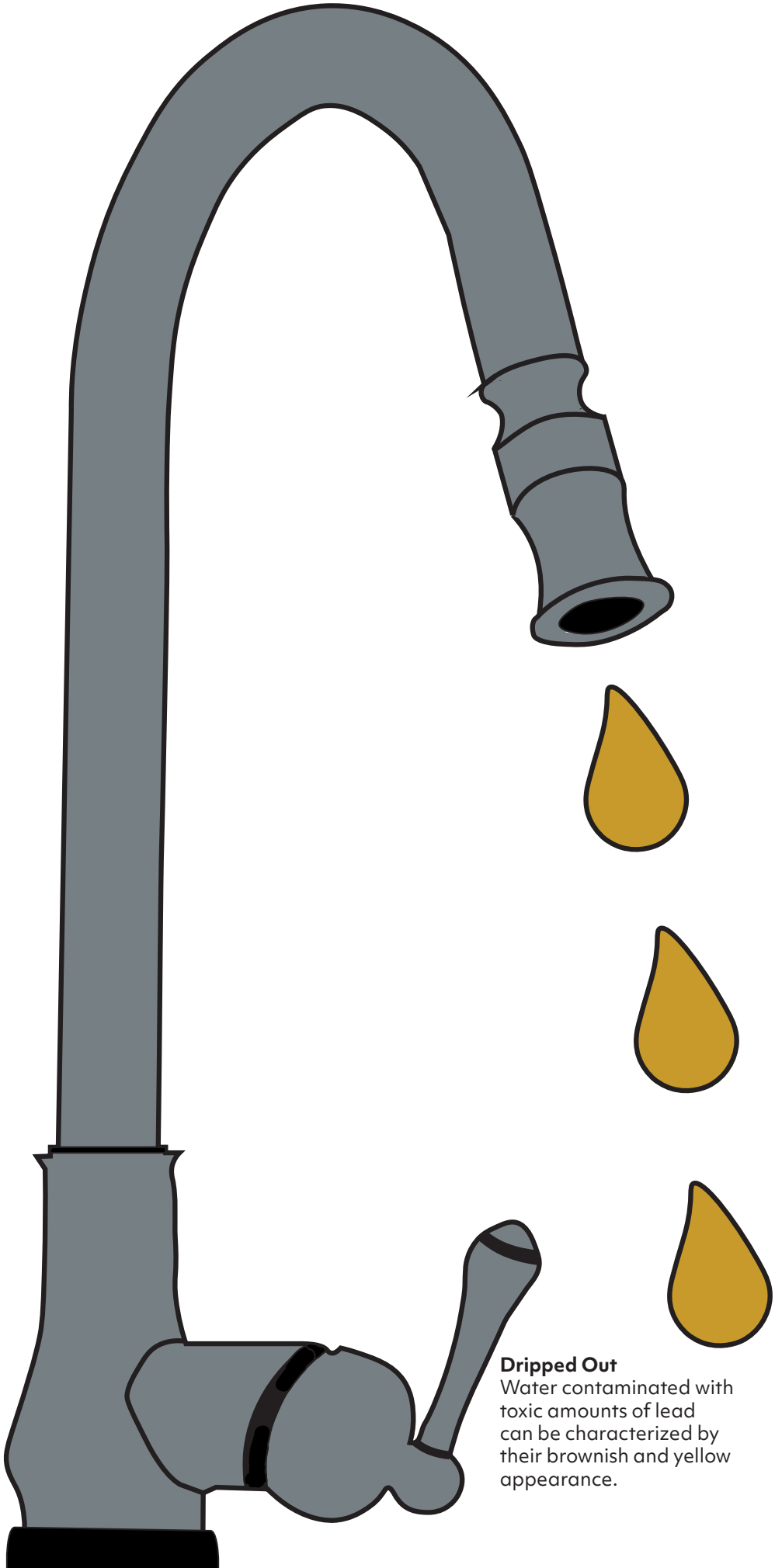
An example of harmful chemicals is that of "forever chemicals," also known as PFAS, which are resistant to breaking down in the environment. Found in non-stick cookware, food packaging and fire-fighting foam, they are prevalent in most areas worldwide. The biggest issue with these forever chemicals is they can cause sickness, including cancer, liver damage and developmental problems when in high concentrations. These chemicals have found their way into virtually every water supply worldwide. If there is no effort to slow the production of these chemicals or remove these chemicals from the water supply, the concentration of these chemicals will perpetually increase.

Though forever chemicals threaten water supplies around the nation, Dallas has done a great job of limiting the number of these chemicals in the water supply. Denis Qualls, superintendent of DWU, explains that there is currently 1 part per trillion, or "1 drop in 500,000 barrels," of forever chemicals in our water supply.

Natural disasters, pandemics and other significant events could harm the water supply. Infrastructure could get destroyed in a natural disaster, and people might not be able to work due to a pandemic, putting the ability to source Dallas with sufficient, safe water at risk.

After hearing from Denis Qualls and Alicia Lee from DWU, it seems like many of the issues that Dallasites face are either already resolved or are planned to be resolved in the near future. They shared Dallas' 500-page water supply plan titled 2014 Long Range Water Supply Plan, which details Dallas's goals to "preserve the quality and quantity of Dallas's water for now and for future decades" (Lee). It is excellent to know that DWU's leaders have the citizens' daily necessities as their top priority.

Story John Householder
Graphic Michael Gao



Dripped Out
Water contaminated with toxic amounts of lead can be characterized by their brownish and yellow appearance.

Destroying the Wild Side of Life

With the increase in industrialization and consumption of natural resources, nature is slowly fading into history.

Armies of Pylons
The rows of pylons show how industrialization is slowly robbing nature of its domain.

Dried-up creeks. Flooded towns. Vanishing glaciers. Tsunamis. Droughts.

While we often attribute effects like these to the climate crisis, in many cases, they point to deeper problems and implications—namely, habitat loss and environmental destruction. Throughout the years, the more-and-more frequent stories only go to show how pressing of a problem habitat loss is becoming. However, with the help of environmental efforts, there are ways to help slow the process down—and hopefully, work toward stopping it altogether.

Habitat loss is the destruction, degradation, or fragmentation of natural habitats, such as forests, wetlands, grasslands and infrastructure development. Climate change makes it hard for some species to adapt and thrive. Each activity clears land, whether a forest, prairie, or other biome, to make room for human activities or gathering resources.

Some effects of habitat loss include loss of biodiversity, fragmentation of habitats, disruption of ecosystem services, climate change and human/wildlife conflicts. All of these effects are tied together—when habitats become fragmented or lose essential parts that allow them to function correctly, the habitat will lose some of its diversity as certain species of plants and animals lose an integral part of their habitat. When habitats cannot support all the life they are supposed to, ecosystem services—including water purification, air quality regulation and carbon sequestration—stop occurring. Finally, closer contact between the habitats and humans causes more harm than good, as natural human occurrences degrade the environment.

According to Akash Munshi, St. Mark's resident botany specialist, habitat loss is already prevalent in Dallas, especially in the Blackland Prairie. "The prairie is sometimes called 'upside down forest' because these roots go down more than 25 feet," Akash said. Though the Blackland Prarie is a vital Texas ecosystem, it has been slowly dying off due to climate change. The native prairie grasses are essential to the prairie ecosystem because, with the loss of native grasses to anchor the land, the topsoil will get blown away, exposing the ecosystem to harsh conditions and making it harder for the ecosystem to survive.

Studies have shown that habitat loss is directly associated with climate change. Plants act as carbon sinks, soaking up carbon dioxide in the air and output oxygen. "To link it all together . . . if you're

removing habitat, you're removing large . . . carbon sinks," Akash said. Loss of these carbon sinks, trees, means that the Earth will convert less carbon dioxide into breathable oxygen, which, in turn, will worsen the problem of climate change. The world has already seen the adverse effects of deforestation in the Amazon basin, which has massively contributed to global warming in the past several decades.

Akash also presents one of Texas's leading causes of habitat loss: the growth of suburbia. "One of the worst things you can have in your yard, and this is everywhere, is have invasive grass, [like] Bermuda grass . . . It's just it's used to landscape everything," he said. Instead of using native grasses, homeowners usually opt for non-native grasses like Bermuda Grass, which is lush and visually appealing but an invasive species requiring tons of water to landscape. On top of clearing land for suburbia, which already harms the environment, city planners and homeowners constantly replace native plants with invasive plants that require special attention and harm the ecosystem around them.

"What people need to do is switch to a native grass," Akash said, "There's an example called buffalo grass. After you seed it, you have to water it for about one month, and then you never have to water it again, and you never have to mow it. And in my opinion, it looks much better," he said. Using buffalo grass is a great solution to help build and retain the environment while creating a yard for a home, as it is a win-win situation for both the environment and landscaping.

"Not really enough is being done," Akash said when asked about efforts to protect the environment. However, he has taken it upon himself to help save the prairie ecosystem. Akash is passionate about helping the ecosystem, and his nonprofit and school club, Cultivation Nation, helps restore the Blackland Prairie. He is currently working on restoring 14,000 square feet of the Blackland Prairie with native grasses with the hopes of helping reform the topsoil and repair the damaged ecosystem. He recently held a service opportunity for St. Mark's students to support part of the prairie by planting native grasses and topsoil in needed areas.

Akash and his non-profit have already planted three to four thousand plants.

"We're going in and planting every weekend," Munshi said, "we've rescued chunks of prairie that are slated to be destroyed."

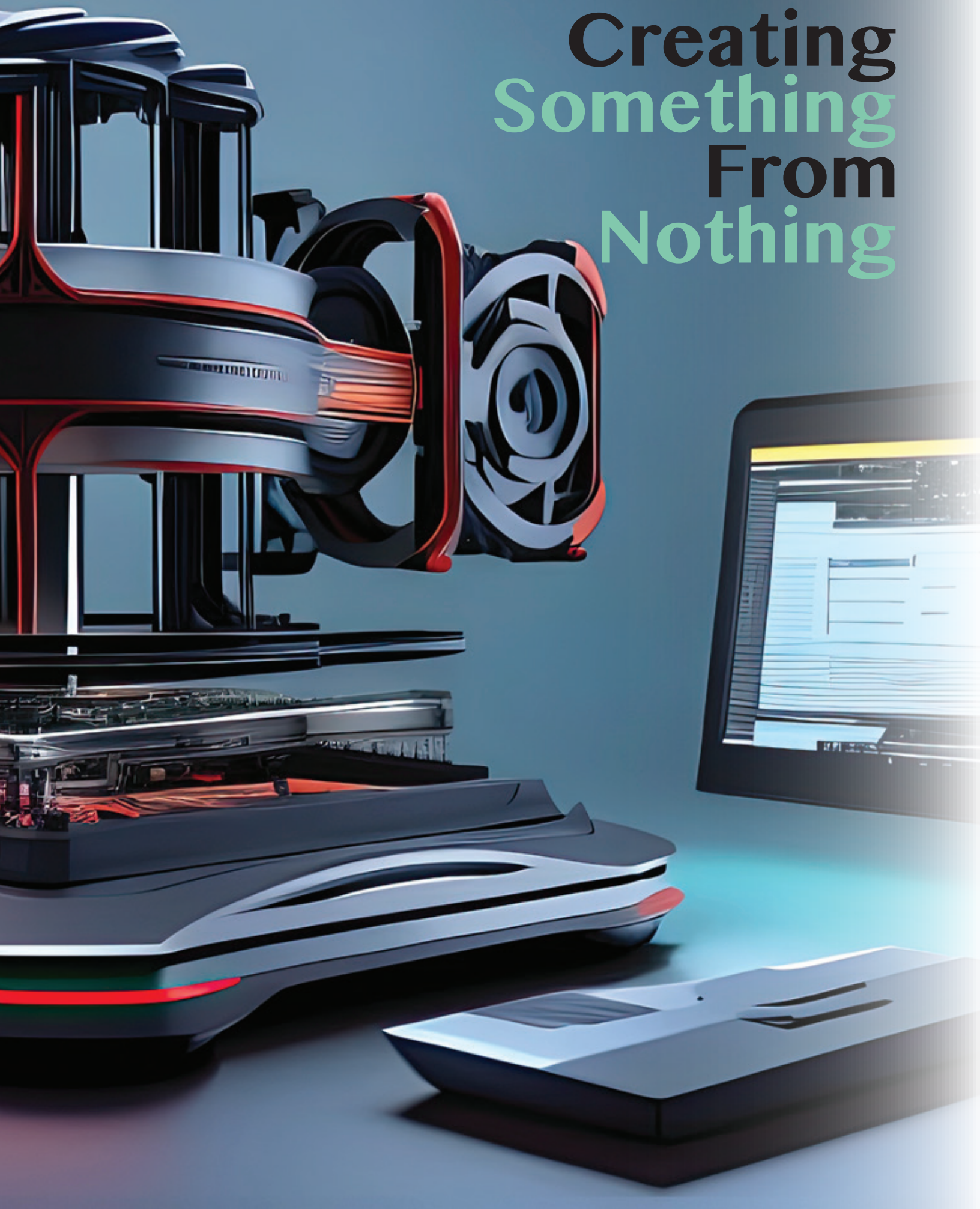
Interestingly, habitat loss can sometimes be caused by forestation.

"One example of the degradation of the prairies [is] actually forestation on the prairies. I mean, these deciduous trees are coming in," Munshi said. If trees start growing on prairies due to global warming and restricted ranges, the plants that have flourished on these lands for hundreds of years will eventually be destroyed. Therefore, an essential part of retaining the habitat is ensuring that separate biomes are not mixed so that one will get eliminated.

Even though all these habitat problems are plaguing the world, it is reassuring to know that people in the St. Mark's community are helping battle this big environmental issue of our generation. It is also great to know that anyone can help, whether donating to his and other non-profits that help combat habitat loss, landscaping with native grasses, or even planting or caring for a pollinator garden. Habitat loss is a global issue, but with every individual's consistent effort, the problem can and will get resolved.

Story John Householder
Graphic John Householder

Creating Something From Nothing



In order to keep up with modern innovation, Junior Vivek Patel has learned and applied various methods of additive and subtractive manufacturing to build world-class robots.

3D printers. Mills. Laser cutting. In our world of rapidly growing technologies, it's not uncommon to find new inventions available online daily. From revamped car frames to ever-improving phone cameras, we see so much "new" wherever we turn. Behind each of those developments lies a crucial yet under-discussed topic, without which nothing would be possible: manufacturing. For people like junior Vivek Patel, it's a branch worth making a hobby out of.

Patel took his first step into manufacturing while working on designs for robotics teams, including the school's BEST Robotics team and a world-class First Tech Challenge (FTC) extracurricular team.

"Manufacturing is about producing parts you design," Patel said. "There are two major types of manufacturing: additive and subtractive manufacturing. With additive manufacturing, that's usually done with a 3D printer since you're adding material onto nothing, while subtractive manufacturing can include tools like laser-cutting and CNC-ing with a mill, where you take a block of material and cut it down to the design."

While manufacturers frequently use both methods, each has its advantages and disadvantages. With additive manufacturing, the main benefit is that it allows for the creation of almost any design from the ground up. Some additive manufacturing methods include fused deposition modeling ("3D printing") and powder bed fusion, which melts material powder with a laser to create parts.

"3D printing is really versatile; you can produce pretty much any shape you can think of," Patel said. "That means that you can create really complex geometries, and that's why it's really great."

On the other hand, subtractive manufacturing involves removing parts from a whole, chipping down a shape already set in stone beforehand. Also called machining, subtractive manufacturing has advantages in large-scale manufacturing, such as in sculpting or metal milling.

"In my case, using subtractive manufacturing on wood and laser-cut materials allows me to make certain assemblies pretty conveniently, but in general, it's a little bit more limited than additive manufacturing," Patel continued.

In the real world, manufacturing finds its roots in various industries, one of the biggest being the automotive industry. In particular, parts like car engines go through over twenty milling machines in the long production process. For Patel, though, manufacturing exists to extend his hobbies.

"By applying manufacturing to my interests, it's enabled many different projects that I'm currently undertaking, whether that be robots, computers, or just any other building assignment faculty members throw at us," he said.

Fortunately for Patel, the Makerspace here at St. Mark's includes a variety of key manufacturing machines, each serving its own purpose.

"We have access to 3D printing, a type of fused deposition modeling (FDM). We also have a CNC router, which can cut wood and some aluminum sheet metal," Patel said. "CNC just essentially means computer-numerical controlled or just computer-controlled manufacturing, which allows for the machine to do the cutting instead of humans. We have two different types of CNC router machines: a huge four feet by eight feet one and a CNC lathe that we use to cut more complex metal parts."

"By applying manufacturing to my interests, it's enabled many different projects that I'm currently undertaking, whether that be robots, computers, or just any other building assignment faculty members throw at us"

A CNC lathe spins a metal block at 3000 rpm and trims the block down layer by layer into the desired shape. In addition to CNC allowing for 2D cutting, the Makerspace has a user-friendly wood-cutting machine.

"We have a laser cutter that's really versatile," Patel said. "For wood and different types of plastics, it's very precise and requires little pre-programming. In fact, it's really plug-and-play."

For simple geometries like laser cutting shapes, a 2D file is the standard input format. In fact, most simple sketches could easily be cut by the milling machines too.

"But for more complex parts, such as the parts I make on the CNC lathe or the 3D printer," Patel said, "I need to use more complex software, that way, I can 3D model an object to export to the machine."

For this purpose, Patel uses CAD software or computer-aided design software.

"Computer-aided design is essentially 3D modeling—so just taking whatever you have in your head and putting it in software so that you can visualize it on your computer as a 3D model," Patel said.

But CAD goes beyond school-level projects—its applications extend far into engineering-related industries. In addition to fabricating new components, CAD simulates real-time tests before manufacturing happens. For example, simulated joints are commonly used to determine how parts would move in real life, while stress analysis simulations allow engineers to reevaluate designs quickly.

"A lot of companies, like SpaceX, use CAD to create different types of parts," Patel said. "Pretty much any engineering-related field is using manufacturing and CAD."

In the world of CAD, mechanical engineers also have a toolkit of software —such as Fusion 360. In Fusion 360, users make and extrude sketches into a 3D plane. One of the main benefits of Fusion 360 is that it doesn't require the user to create the component out of regular 3D shapes, giving the user more freedom.

Blender—another popular software—allows the user to accurately simulate the effects of stress and lighting, effectively creating a hyper-realistic environment. The intricacies of the Blender environment help visualize the working prototype, allowing engineers to discover design flaws before the product is officially manufactured.

"Beyond iterations upon iterations of design optimization, there's still more to explore—such as the preferred raw materials," Patel said. "Depending on the manufacturing process, different materials may be used, such as specific metal alloys to withstand different forms of stress, and cost-effectiveness given the target audience and use case. Where wood suffices, expensive metals would never be used."

Within the manufacturing realm, engineers have so many variables to test, which allows them to improve designs and aim for the optimal. But beyond the complexities and intricacies of the whole process, the beauty of manufacturing stands as something much simpler: to enable people to create anything they dream of and bring it into reality.

Story Joseph Sun
Photo Joseph Sun

Section III: DEPLOYMENT

Deployment: putting ideas into action. "Deployment" represents the final step of artificial intelligence—implementing a machine learning model in real-world situations to perform tasks and solve problems. It describes the innovation and technological advancements that scientists have created. It's also the culminating step of a Marksman's journey: using the data he's collected and the training he's received to impact the world in previously unimaginable ways. "Deployment" contains the wisdom of alumni and community members who have climbed to the highest of highs and dove to the lowest of lows, whether that be leading the advancement of virtual reality programs, developing novel ways to fight deadly diseases, or helping to alleviate climate change's impact on global ecosystems. This section serves as a reminder of the greatness that has come before, empowering future generations of Marksmen to change the world.

AI Deployment

Adventures of Victor Vescovo ‘84

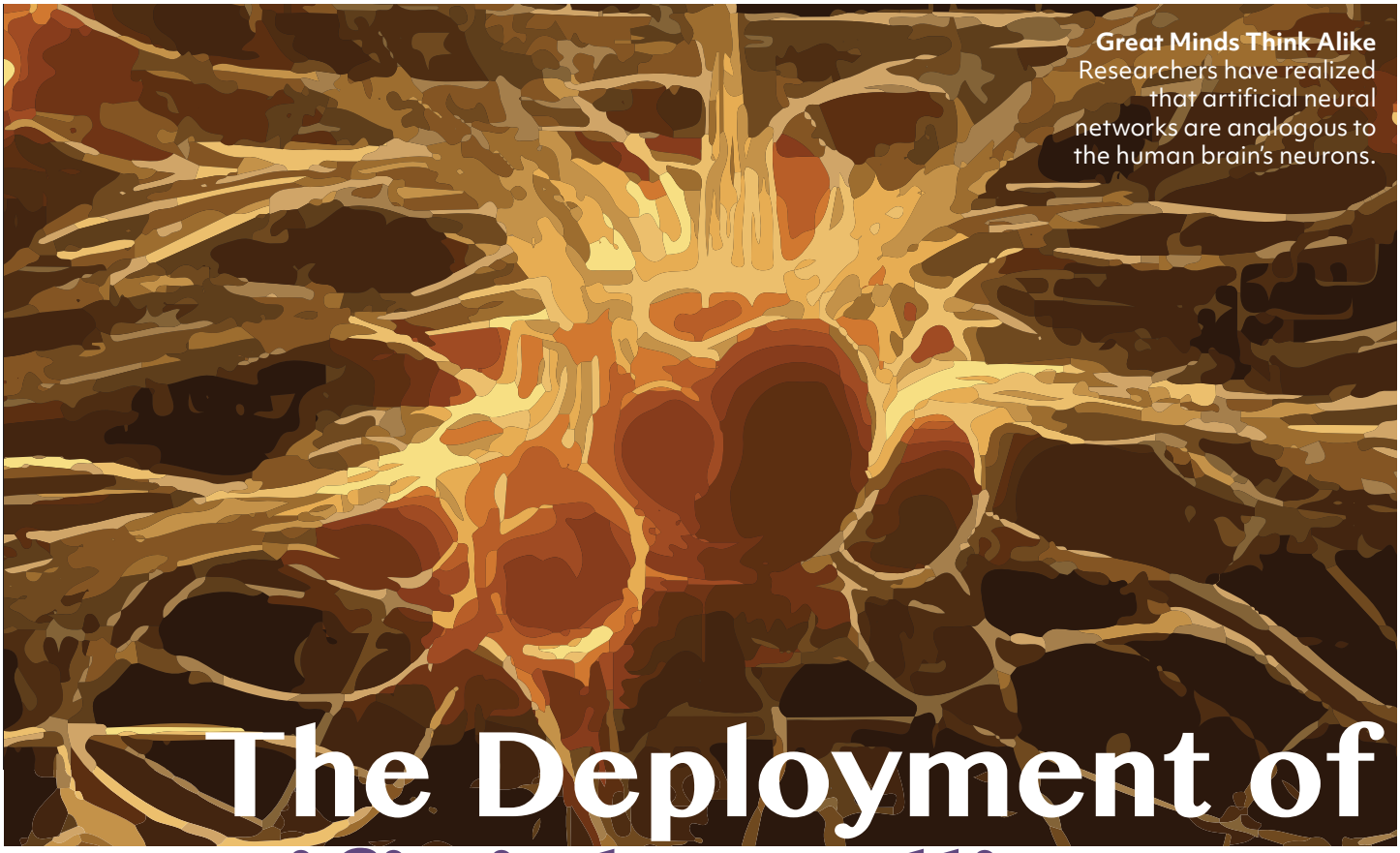
Processed Foods and the American Diet

Coral Bleaching

Future Water Supply?

AR and VR in Education

Nanoparticles in Immunotherapy



Great Minds Think Alike
Researchers have realized that artificial neural networks are analogous to the human brain's neurons.

The Deployment of Artificial Intelligence

Ever since Christopher Starchy created the first AI, the world has been mezmirized by the range of implementations and possibilities with this amazing technology.

Artificial Intelligence has taken the world by storm and revolutionized virtually every sector of society. From its role in rapidly sequencing RNA for vaccines to making lightning-fast decisions on the stock market, the transformative power of AI is reshaping the very fabric of human life.

AI is generally classified into 3 types based on intelligence and ability level as compared to a human. The first is artificial narrow intelligence, or ANI. ANI generally has very narrow capabilities and is generally used to perform repetitive and/or mundane tasks humans could also perform quite easily. The second type is artificial general intelligence, or AGI, which has intelligence and capabilities equal in ability and speed to that of humans. The most advanced type of artificial superintelligence is ASI, which has a more complex thinking process and can perform actions at a much better and quicker rate than a human. The level of most modern AI lies around the level of artificial general intelligence, and many programmers are developing AI that could reach the level of artificial superintelligence.

AI's main advantages over humans compound twofold; by processing and training with large amounts of data, machine learning programs can more precisely and accurately make decisions and perform tasks that humans would otherwise find difficultly in doing. Additionally, AI has the potential to replace humans in a wide variety of jobs. Being faster, more accessible, and more precise, using AI is a no- brainer. For this reason, AI is rapidly being adopted by companies to perform various tasks.

The IT sector has the most immediate benefit to gain by adopting AI. Enhanced speech recognition, image processing, and advanced diagnostics are only some of the many possible uses for AI in the IT industry.

In addition to IT, the financial department has great potential gains from the deployment of AI. There are so many possible implementations of AI within finace. Firstly, AI can analyze stocks and determine optimal trades through their ability process large amounts of data to predict the future behavior of the stock market. Beyond basic trading, AI models called "Robo advisors"

can analyze a specific company or merger and recommend to an user the best course of action. A new study found that almost one-third of high-net-worth investors are utilizing Robo advisors for financial advice.

Another industry primed to significantly benefit from the deployment of AI is the medicinal sector. AI has the ability to complete routine medical tasks that require high accuracy, such as measuring out the amount of anesthesia to give a patient or making precise cuts during surgery. By reducing medical errors, AI can potentially save thousands of lives and billions of dollars, as according to John Hopkin's Medicine, it has been estimated that human medical errors kill around 200,000 people per year and cost around 2 billion dollars per year.

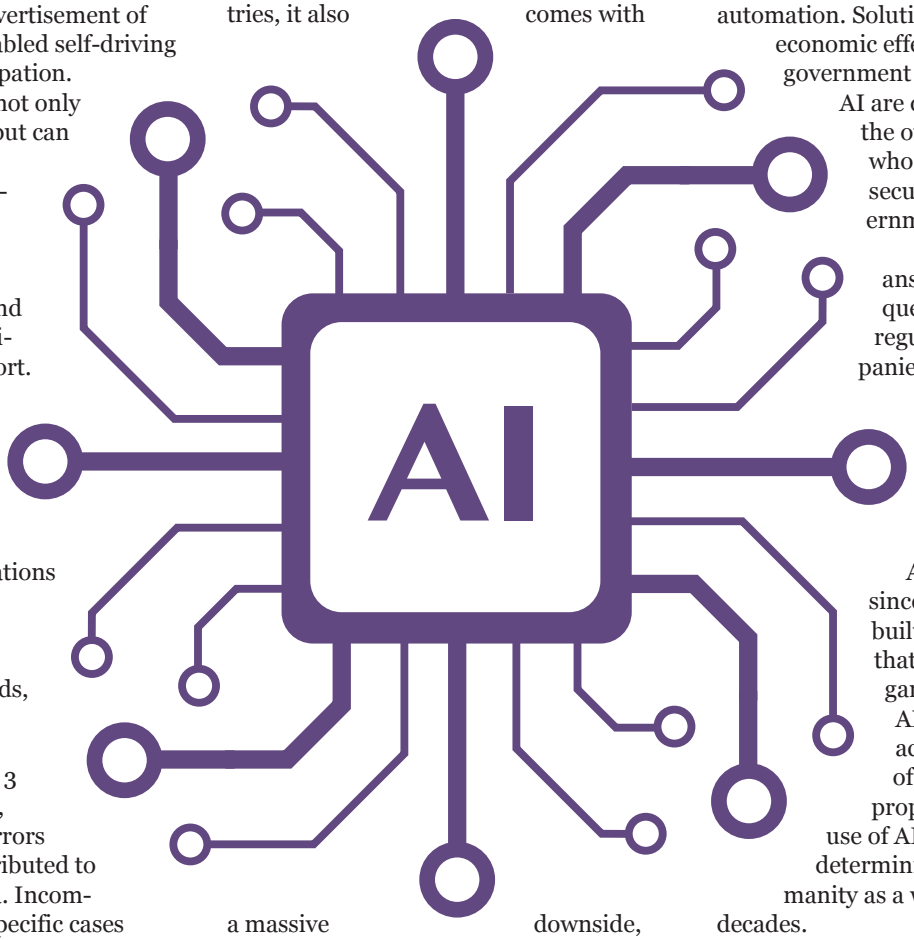
Transportation and infrastructure is the most mainstream advertisement of the benefits of AI. AI-enabled self-driving cars fill many with anticipation. Automated vehicles can not only help the general person but can also streamline shipping and transport, fixing supply chain issues that cost billions of dollars every year. In addition, AI can automate public trains and buses, ensuring more efficient and reliable transport.

AI will allow humanity to do things never done before. From jobs too dangerous for humans such as deep-sea mining, to computing calculations impossible for a human, AI will unlock numerous advances in humanity.

AI holds great rewards, but will also come with unwanted risks. AI risks can be broken down into 3 categories: error, misuse, and superintelligence. Errors by AI systems can be attributed to issues such as faulty data. Incomplete training or hyper-specific cases provide major issues for potential uses. For example, the introduction of AI into financial markets has created a risk of financial instability. Specifically, failing to account for market interconnectedness or cultural factors that influence the valuation of a company coupled with the fact that AI systems trade thousands of stocks every few minutes creates massive potential for financial instability. The 2010 Flash Crash or the Knight Capitol Flash Crash are examples of times when AI errors created drastic effects on the stock market.

Lastly, a superintelligence possesses one of the biggest risks to modern humanity over the coming decades. While the TVscenarios might seem like something far from reality, the risk of mal-intentioned AI is very real. AI has the potential to develop goals that are misaligned with humans or devalue human life. However, Many of these examples are worst-case scenarios, and the industiry is still many years and potentially even decades off from developing "true" superintelligence, and safeguards, as it relates to AI research and deployment, will be able to prevent nightmare scenarios. Regardless, it is important humanity takes precautions when developing AI systems and prioritizes safety and ethicality over speed and profits.

While AI has the potential to create massive benefits for many industries, it also comes with a massive downside, namely job losses due to automation. By 2025, 85 million jobs around the world are expected to be lost due to job automation. These are mainly jobs such as accounting or cooking, that can easily be performed by an AI system. In a post-COVID world where many Americans are quitting low-paying jobs to pursue other interests, it may seem like automating jobs with AI is a good thing; however, the dilemma of how much is too much arises. While right now, AI is only replacing low-skilled jobs, in the future AI could potentially perform any job a human could both better and faster. From AI robots that can perform surgeries, to AI softwares that can take meeting notes and create reports, to AI utilities that can cook food, a recent study by the University of Oxford found 47% of all jobs can be automated by AI, and that number is only set to increase as AI systems get stronger.



Naturally, companies would be incentivized to fire human workers and replace them with AI workers, as AI systems are cheaper, available 24/7, and more efficient than humans. Only a handful of jobs such as therapists, litigators in court, or teachers would be safe from AI automation. Even if AI was unable to automate the vast majority of jobs, the most conservative estimates still conclude that AI would be able to replace at least 25% of the workforce through automation. Solutions to the inevitable economic effects such as excessive government regulation of the use of AI are difficult to enforce, on the other hand, giving those who lost their jobs social security would cost the government a fortune.

There is no clear answer to any of these questions, and government regulators as well as companies and citizens will have to figure out the best way to manage both the risks and rewards created by AI to maximize its benefits for humanity.

AI has come a long way since the primitive machine built by Christopher Starchy that was able to complete a game of checkers in 1951. AI deployment will only accelerate over the course of our lifetime, thus proper management and use of AI will be a key factor in determining the well-being of humanity as a whole over the coming decades.

Many will look to the future exited for the new possibilities, some will look in terror of the possible side effects, but one thing is sure, AI is coming, and nothing can stop it.

Story Richard Wang
Source John Hopkins
Graphics Benjamin Chen

Adventures Beyond the Lions' Den with Victor Vescovo

Victor Vescovo '84, investor, retired naval officer, sub-orbital spaceflight aeronaut and undersea explorer, shares his tales of adventure and daring.

Benjamin Chen: How did you first get introduced to this world of exploration and scientific discovery?

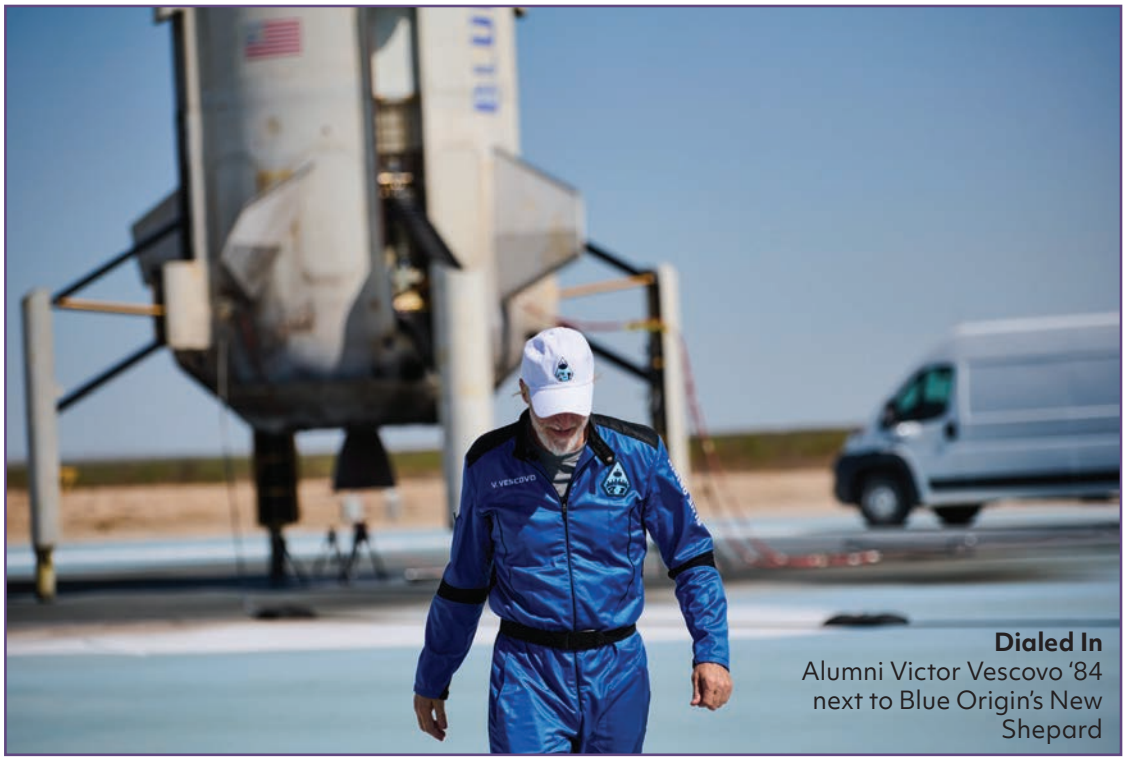
Victor Vescovo: I imagined I became involved slowly over time, and it started with mountain climbing from the time I was in my twenties. It eventually led to me climbing Everest, which thousands of people have gotten, but certainly, it's not the easiest thing to do. But I really got involved in scientific exploration when I helped design and build the deep-submergence vehicle, Limiting Factor, which allowed me to go to the bottom of all five of the world's oceans for the first time. As part of that mission, I had an extensive outreach to the scientific community so that they could discover new things where no human has ever been before.

BC: What inspired you to push the boundaries of human exploration in the Five Deeps Challenge?

VV: I had been mountain climbing for several decades, and it was getting more dangerous as I got older, so I was looking for a different type of extreme challenge, one that required more mental, logistical, and financial requirements. I was shocked to discover in the year 2016, when I was thinking about this mission, no human being had been to the bottom of four of our world's five oceans. It just struck me as absurd that with all the technology we had available that that had never been done before. Richard Branson had tried it once before, but the technology he chose didn't work. I tried to learn from him and from others and put together a team. Then we were able to figure out that we could, in fact, do it with the resources I was willing to commit. It was just something I thought should have been done by that point, and no government or other individual was on the path to do it. And so I thought it'd be a great adventure and a great technological push for humankind.

BC: How did this recent Mauna Kea expedition compare to your previous challenges, such as Everest and Five Deeps?

VV: Well, climbing Everest is probably



Dialed In
Alumni Victor Vescovo '84 next to Blue Origin's New Shepard

one of the most difficult things I've ever done just because it is so incredibly physical, and you are really torturing your body to take it up to those extreme altitudes in areas literally called the death zone. The earliest dives in the submersible were also very challenging because it was a very new system, and we were still working out a lot of issues with it. By the time we executed the mission to do the first full ascent of Mauna Kea from the base of the volcano, on the seafloor, at about 5000 meters to its summit, which no one had ever done before, the submersible was working very well, so the challenge was more of a physical one. In fact, now that I think of it, it was an odd combination of my diving experiences and my mountain climbing experiences, which I really hadn't done before. I was able to use the submarine on the first half of the expedition to go down to the bottom and then float to the surface and then kayak, bicycle and climb to the summit of Mauna Kea, which was very physically difficult for about two solid days. We were able to do it with me and a native of Hawaii, and it was a great experience. I think we were trying to just bring attention to the ecosystem that is not just on the land but in the water. It also makes a cartographic point that the world is very interesting and that the tallest mountain, by some measures, is necessarily not what you think it is.

BC: How does your body respond to continuously being this active at 57? And how do you take care of your body so you can remain an active explorer?

VV: Well, I just turned 57, so I think one part of staying healthy is just being active your whole life. I started as a youngster, bicycling and running, and then at St. Mark's, I continued that. I was on track and field, I played football, I played soccer, and I just continued that level of activity throughout my whole life, and I think that primes you to undertake even more difficult things with the appropriate level of training. And a lot of it is mental. You simply have to make a commitment to do these difficult things, to get off the couch, and put in the time and the training to prepare yourself for some very difficult missions. They're very rewarding when you complete them, and I think that so many people never really push themselves physically because I think inherently we're kind of lazy, but it's a choice to push yourself and do, hopefully, noteworthy things in your life.

BC: Other than your famous encounter with plastic at the bottom of the Mariana Trench, what experiences have affected your perspective on climate change and human waste?

VV: One of the more distressing encounters I had on the bottom of the sea floor was actually at the Calypso deep, which is the deepest point in the Mediterranean Sea. I actually had as my copilot Prince Albert II of Monaco, who's the head of state of Monaco, and unfortunately, on that dive, we saw the greatest amount of human contamination, not just plastic, but large cables discarded from ships, all sorts of clothing. Anything you could imagine people would throw into the ocean was down there. It was very distressing, but at the same time, it was very helpful to have Prince Albert there because he has the ability to reach a lot of people. That experience allowed him to speak firsthand just how much we contaminate the ocean and that we should not do that as a matter of course, that if you put something in the ocean, it doesn't disappear. It just moves into a different place and contaminates the environment in the life that lives there.

BC: Do you plan to start an organization specifically about climate change as issues continue to grow?

VV: I'm a technologist, first and foremost, so I see my role as enabling technology that will allow scientists and others to explore the world more thoroughly and effectively. If I happen to make observations myself that can help in certain parts of the debate, I will do so. For example, I've become more involved in discussions about mining the seafloor for minerals that could be used for electric vehicles. It's a very complicated debate, but I'm becoming more involved in criticizing the current plans that exist to mine the seafloor in the manner they wish to. I think it's very destructive and not economically viable. That's an example where I will participate in the debate, but I don't think I will be involved in the creation of any organization or leading large movements on certain environmental topics.

**continued on next page*

The Sky's the Limit
Vescovo poses next to the entrance to Blue Origin's New Shepard and points to the stars.

The Lone Star
Vescovo proudly holds the flag of his home state, Texas

BC: How do you think space exploration and industries such as asteroid mining and space manufacturing will benefit or harm humanity?

VV: I believe very firmly in space exploration. I find it amusing when people try to pose the question to me, should we be exploring the deep oceans, or should we be exploring space? And I don't believe they are exclusive. I think we need to do both. And I believe that those areas can contribute a great deal, not just to scientific discovery, but to finding things out that can help us live as humans here on Earth. Having thousands or even millions of people working and living in space is the objective of Blue Origin, whose rocket I went into space on. They believe that we will find new discoveries and new ways of manufacturing and living that can substantially benefit the people here on Earth. Like some of the things you mentioned, potentially asteroid mining, or manufacturing, things that are toxic in space away from the atmosphere, or any number of things could be developed in space that we simply can't do here on Earth.

"I believe very firmly in space exploration. I find it amusing when people try to pose the question to me, should we be exploring the deep oceans, or should we be exploring space? . . . [W]e need to do both.

BC: Looking back at your time at St. Mark's, what would you consider to be the best out-of-class experiences you've had here?

VV: What immediately came to mind for my best out-of-class experiences was simply the time I spent with the friends that I made there. That is the honest truth. I still have deep connections with friends that I made in my very first year in seventh grade at St. Mark's, and I will have those close relationships until the day I die, I'm sure. Spending time with them on Friday and Saturday nights doing what we did back in the 80s, watching movies, going to the record store and having dinner, are some of the most cherished memories I will ever have. That is something I think St. Mark's fosters very well and is underappreciated when you're there.

BC: Addressing the St. Marks community with your wisdom from a life of exploration and science, what would you want to say most?

VV: I've been to a lot of places and worked with a lot of great people. If there's one thing that stands out to me, it is the most important quality I think that an individual can have is self-discipline. Because if you have self-discipline, all you have to do is to decide to do something, and then you will, through that discipline, carry it through. But I think there's a human tendency not to be disciplined and, therefore, not achieve all that we can in life. I think that St. Marks is a wonderful institution for helping to foster self-discipline. Through studies, through athletics, through nurturing relationships, that is a very challenging time in our lives when we're in our teens.

Interview Benjamin Chen
Photos Courtesy of Vescovo

The Consequence of Convenience

The American diet and its processed foods are notorious for their high caloric value, lack of nutrition and obscene amounts of sugar, fat and salt. We talked to nutritionist Kristie Adame about the epidemic.

Over 40% of the American population is obese, according to a 2020 report by the National Institute of Diabetes and Digestive and Kidney Diseases. However, instead of plaguing the wealthy, as many would expect, obesity ironically affects those with the least amount of money to spend on food. Because of the expensive costs of fresh produce and meat, underprivileged families must instead live off processed and fast foods.

Unlike vegetables and fruits, processed foods have little to no healthy vitamins while still containing massive amounts of sugar, fat and salt. Because the human body is hardwired to love sugar, fat and salt, these foods are highly addictive and palatable. Thus, it's very easy for people to get hooked on fast foods and processed sweets—a tendency especially problematic for those with no other options.

"I work primarily with people with diabetes, and a lot of these people also have other health issues, such as high blood pressure, high triglycerides and high cholesterol." dietician Kristie Adame said, "They also have what's called non-alcoholic fatty liver disease, and that has become very common in people with type two diabetes and even pre-diabetic patients. We're seeing more evidence that processed foods are causing more fat, not just on people around their waists but also around their livers, which can cause their livers to necrose over time. And they can have cirrhosis, the formation of scar tissue on the liver, like people with alcoholism. Obviously, there's more to it than just processed foods, but people who have a high intake of processed foods tend to be at higher risk for pre-diabetes, obesity, et cetera. So we know that they are causing weight gain, which causes more insulin resistance and high cholesterol levels."

Kristie Adame
RD, LD, CDCES
Dietician at
Parkland Hospital

Apart from the sheer amount of sugar present in these foods, the type of sugar is also to blame for the rise in obesity. High fructose corn syrup, a common sugar substitute, is present in a wide variety of foods from sweet treats to seemingly-healthy granola bars.

"High fructose corn syrup is in a lot of highly processed foods. And obviously, it's a processed sugar, but the way it's made up, the way the body breaks it down, and how it affects the body is different than just regular sugar. And when people eat them on a regular basis, they tend to develop fatty liver disease." Adame said.

Unlike glucose, fructose can only be metabolized in liver cells. By eating processed foods saturated with high fructose corn syrup, the liver is overloaded with fructose. As a result, the liver turns the excess sugar into fat, which causes the body to develop fatty liver disease. Eventually, the fat clogs and messes with the blood flow throughout the liver, causing liver cell death and cirrhosis.

Apart from fructose, misinformation is also the culprit. Today, many people still falsely believe that fat causes fat and that all these health complications arise from fatty foods. Instead, sugar is the real culprit.

"As far as when you're eating carbohydrates, which is any form of sugar, your body has to produce insulin to metabolize that sugar." Adame said, "Some people cannot produce insulin because of their genetics. That is type one diabetes. But the one associated with weight gain and insulin resistance is type two diabetes, which many of my patients have. And in my years of experience, I have realized that carbohydrates are the real culprit, not fat. I am not saying that guzzling down gallons of fat is healthy. In fact, some processed fats can also cause problems with people's health. But I think there is more of a blood sugar insulin issue in America than fat."

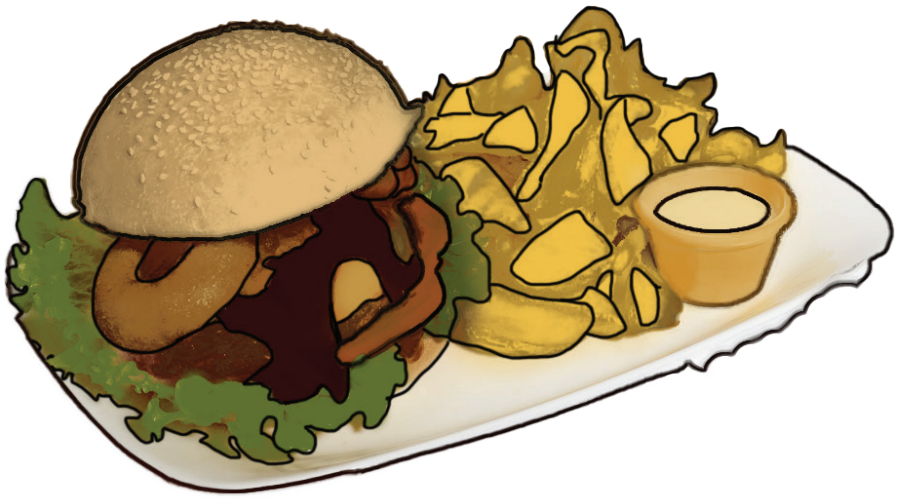
To combat this obesity epidemic, Adame spreads awareness to her patients about what they are putting in their bodies versus the things they really should.

"The easiest way is to look at an ingredient list," Adame said. "See how many ingredients there are in the food. And this may sound funny, but how much of it can you pronounce? How much of it do you understand? How much of it is just basic ingredients like sugar, salt and oil versus the list of preservatives? I tell people that if it's got more than five ingredients and the majority of it you can't even pronounce, that's a red flag and that's probably not something that you want to eat regularly."

Adame also encourages her patients to eat more vegetables in general and not follow the latest diet craze. Since most of these diets are relatively new, the science backing them up is sparse. Thus, Adame cannot confidently say to her patients that some new diet trend will work miracles or solve everything.

"I'm always going to encourage more plant fats than animal fats. As of now, we don't know the long term impact of somebody primarily following a keto diet, for example," Adame said. "There just isn't enough science. I definitely don't recommend it for the people that I work with long-term, but I try to keep my mind open. I try to talk to people about why they're doing a certain diet and how long they plan to do it. But overall, in my experience, I encourage a diet with not a lot of red meat, not a lot of pork, not a lot of high saturated type fats, more of your monounsaturated and polyunsaturated fats like nuts, seeds, avocados, things like that. In the long run, I think apart from eating better, you will feel better."

Story Michael Gao
Graphic Michael Gao



Mediterrenean Diet vs. American Diet
Pictured on the top is a Mediterrenean diet characterized by its low amounts of processed foods and high amounts of vegetables and fruits. The American diet below is the opposite. The high amounts of trans fats and processed sugar in the American diet have given rise to a surge in obesity in America.

An Aquatic Forest of White

With global warming and pollution on the rise, the once vivid and vibrant rainbows of the ocean have been bleached into a pallid white.

Housing over 25% of all marine life on Earth and directly benefiting over a billion people, coral reefs are among the most impactful natural environments in the world—covering less than one percent of the ocean floor. Aside from supporting over 4,000 species of fish, coral reefs impact human beings tremendously, providing major sources of food, income and tourism in surrounding regions. But today, more than ever, climate change has continually threatened coral reefs, leading to devastating effects like ocean acidification, ocean pollution, diseases and warming temperatures. These have all led to consistent coral death, with warmer temperatures as the most devastating threat. As ocean temperatures rise, coral bleaching—often the first phase of death for a coral—is a condition most coral never end up recovering from.

Coral reefs reside in tropical oceans and can only survive in a small range of temperatures. Corals live in a symbiotic relationship with a specific species of algae called zooxanthellae. While this relationship varies across coral species, its primary purpose remains: to help feed corals and sustain the beautiful "natural" colors of the reefs. But when ocean temperatures become too warm, the corals expel the zooxanthellae, and all that is left is the white base layer of the coral – coral bleaching.

"We've lost about 60% of the world's corals just in the past 40 years," coral reef researcher Phillip Osborn '14 said. "Scientists estimate that around 90% of all corals will become bleached by 2050, and most of these will not be able to survive." Coral deaths will damage the marine ecosystem, but the process will also impair standard of living and the economy worldwide.

The most significant bleaching events recorded so far occurred from 2015 to 2016, and scientists predict that there will be an increase in temperatures in the Pacific Ocean throughout 2023, leading to more coral bleaching.

But with our hometown Dallas being so far from the ocean, it's easy to forget ocean pollution and coral bleaching. Aside from locals who work closely with coral reefs and professional scientists in the field, coral bleaching is a topic most people have never even heard about.

"People who live, say, Dallas or another area far from the ocean don't have a strong relationship with coral and don't truly understand the critical point we're at right now," Osborn said. "We really need coral reefs to be well-studied and increase awareness to protect them."

"We've lost about 60% of the world's corals just in the past 40 years. Scientists estimate that around 90% of all corals will become bleached by 2050, and most of these will not be able to survive."

In particular, Osborn encourages direct interaction with coral reefs so people can understand the problem firsthand.

"A big problem behind all this is that people don't have a good grasp of exactly what 'coral bleaching' means, and just how gargantuan of problem that really is," Osborn said. "It really comes down to seeing it for yourself with your own eyes, realizing what we're actually losing. I think it's honestly the best way that I would expect people to respond to a crisis like this."

While, as St. Mark's students and Dallas residents, we're physically distant from oceans and reefs, we can still positively impact the W reef crisis by slowing climate change locally. Recent studies have shown that coral can adapt to the changing climate given the right conditions, and they can even thrive—as suggested by research

conducted by Osborn.

"[In one of my research topics,] the professor I was working under hypothesized that coral's physiological properties could play into how they react to stressors in their environment. In other words, bleaching is primarily caused by warming oceans." With this information in hand, Osborn begna testing his group's hypothesis by using models of corals in different aquatic environments.

In continuation of their research, Osborn's group continued observing the tiny polyps which make up a piece of coral and observed the impacts of warmer temperatures on zooxanthellae.

"Our research looked into how the polyps communicated with each other," Osborn said. "We had a few specific criteria on how they communicated with each other, which we used to observe their physiological properties, and essentially, we determined that corals that had polyps and zooxanthellae that were highly integrated were more likely to live through a bleaching event. Similar studies have also shown that corals can adapt if we give them the chance, meaning that more corals could survive future bleaching events."

With higher predicted levels of coral bleaching this year, scientists like Osborn are hopeful that properly increasing awareness could help citizens reduce their carbon footprint.

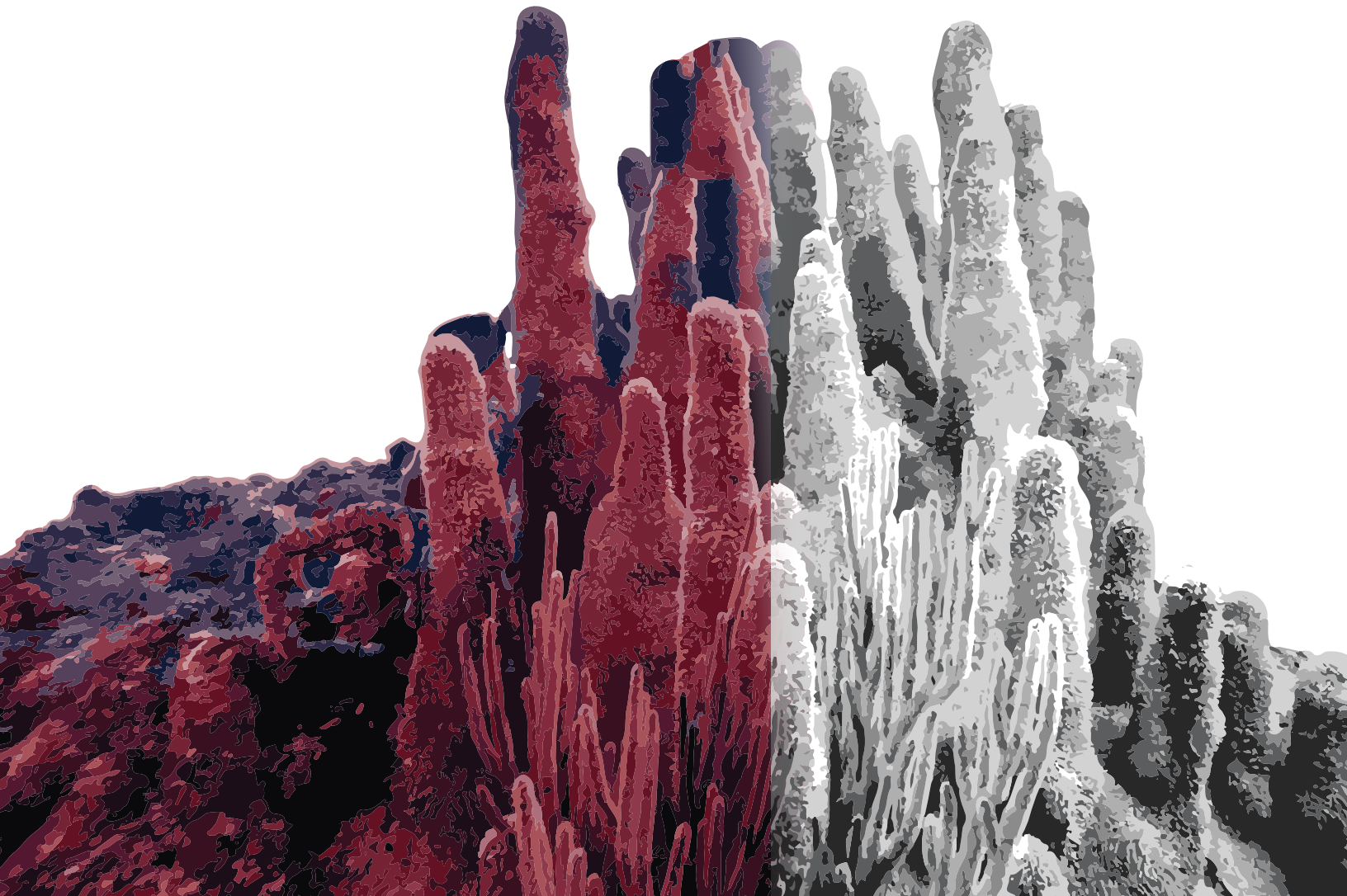
"It's hard to care about coral reefs when you don't see them with your own eyes," Osborn said. "I think that's the biggest issue we face —the lack of exposure, along with so much other bad news in the media all the time. I think emphasizing imagery and trying to get people to see coral for themselves are probably the two biggest ways you can really raise awareness. If you show a beautiful, healthy reef, side by side of that same reef that's either bleached or dead, that's a pretty stark image that sticks with people."

Currently, efforts to save coral have been in the works, like the Netflix documentary Chasing Coral, which details how healthy, vibrant coral gradually transitions into bleached and dead underwater corpses. And while large research teams worldwide are tackling coral bleaching, it's possible for just about anyone to contribute too.

"I did an internship between my junior and senior year of high school down in the Bahamas," Osborn said, "and I was part of the coral team, with one of my jobs being maintaining coral nurseries. We would tie little fragments of the coral to strings, and they would hang underwater, allowing them to grow in a controlled environment. Once the corals were big enough, they would out-plant them and see how they did once they attached themselves to a natural environment."

While nowhere as large-scale as the most prominent research projects worldwide, the experience inspired Osborn's interest in coral reefs and helped make an incremental positive impact over the span of just one summer. Although coral bleaching continues to threaten oceans and surrounding ecosystems today, Osborn is hopeful that the combined effort of small, positive change by many citizens can ultimately turn things around in the future. And while we here in Dallas are far from the ocean, we can also help save coral reefs, one eco-friendly choice at a time.

Story Amar Kakkar
Graphic Michael Gao



Wading in Water

Dallas Now
An artist rendering of downtown Dallas, It showcases the city's urbanization but also abundance of water sources even amidst global warming.

With demand for clean water on the rise, Dallas finds it harder every year to satiate its citizens. Thus, it intends to construct new pipelines and pump stations to better provide Dallas with water.

As Dallas's population continues to grow rapidly, there are growing concerns about the city's ability to provide water to the city's residents sustainably. The city's water supply is managed and controlled by the DWU, the city department.

Dallas Water Utilities (DWU) sources its water from seven places: six lakes, also called reservoirs (Lake Grapevine, Lake Lewisville, Lake Ray Hubbard, Lake Ray Roberts, Lake Fork, Lake Tawakoni), and one river system (Elm Fork of Trinity River). Of these seven, Lake Ray Hubbard is the principal reservoir the City of Dallas owns and operates. Dallas and its surrounding municipalities share the right to extract water from the other six sources.

Water supply is measured in millions of gallons per day (MGD), and Dallas' water supply capacity is 502 MGD. Currently, Dallas residents use 470 MGD daily (around 145 gallons/person/day).

Dallas' yearly 38.3 inches of rainfall is essential to Dallas' water supply. Rainfall fills the reservoirs, and after a wet 2021, almost all of the reservoirs are all above 85% capacity, except one, due to repairs on the dam. Dallas is fortunate to have a predictable amount of yearly rainfall.

As climate change continued over the past few decades, the western part of the United States has become dryer, while the eastern part of the United States has become wetter. Dallas is right in the middle of the United States, and the city has maintained a seemingly predictable amount of yearly rainfall for the past 150 years. The seven lakes/rivers and annual rainfall allow Dallas to continue to have a consistent water supply.

Dallas' thousands of miles of piping carry water miles to its various destinations. Dallas has a total of 12,000 miles of piping. Within these 12,000 miles, there are three types of pipes: water mains, wastewater mains, and storm pipes. Most of these pipes range between 4" and 120" in diameter and carry water to different parts of the city.

However, to pump water to these places, Dallas uses pump stations to pump water through these pipes. Some of Dallas' pump stations are from the 1930s and can pump 50,000 gallons per minute. The newest pump stations can pump upwards of 900,000 gallons per minute. This equates to 72 and 1,200 MGD, respectively. The water from these pump stations goes into the water pipelines and to DWU's customers to be used.

Because of rising water demand driven by population growth, Dallas' current lakes and reservoirs will be unable to sustainably supply the city with water past 2030. The City of Dallas has approved, funded and is currently working on connecting three more water sources and building a reservoir to extend its water supply through 2070. Dallas will do this through four main projects: The Integrated Pipeline Project (IPL), Indirect Reuse through a Balancing Reservoir; a connection to the Neches River; and a connection to Lake Columbia. These projects are projected to increase the water supply to 850 MGD (a 350 MGD increase) and keep Dallas' water sustainable even as the population doubles by 2070.

Dallas' first of four projects is the Integrated Pipeline Project (IPL). The IPL is the construction of over 150 miles of pipelines, three new intake pump stations (two of which will be used in future projects), and three booster pump stations (to help pump water through the 150-mile pipeline). The 9-foot (diameter) pipe will connect Lake Palestine to the current water supply. This project will provide Dallas with an additional 102 MGD, and it will help Dallas meet demand through 2050. The IPL, according to Denis Qualls, superintendent of DWU, is still slated for a 2027 completion.

The second project is called Indirect Reuse through a Balancing Reservoir, where Dallas will construct a reservoir to store discharged non-potable water from the wastewater treatment plants. This reservoir will allow Dallas to treat the water and then use the water as needed. The city will complete this project by 2050, increasing Dallas' water supply by 102 MGD.

The third project is the connection to the Neches River. The Neches River runs south out of Lake Palestine, and the intake pump station, created in the IPL, will pump water into the same pipeline constructed in the IPL, where it will head to Dallas. This project will supply an additional 42 MGD.

The connection to Lake Columbia is the final project to be completed before 2070. Lake Columbia stands 20 miles east of Lake Palestine. Like the Neches River connection project, an intake pump station will pump the water from Lake Columbia to Lake Palestine and then into the pipeline created in the IPL, where the water will head to Dallas. The project will supply an additional 42 MGD, bringing Dallas' water supply capacity up to almost 850 MGD.

Dallas will spend around $3.914 billion on DWU's water projects between 2020 and 2070. The four main water supply projects mentioned above will cost approximately $1.851 billion ($1.097 billion for the IPL, $675 million for the Balancing Reservoir, $227 million for the Neches River Connection and $160 million for the Lake Columbia connection). Not only is DWU executing the above four projects, but DWU is executing sixteen other projects between 2015 and 2070 to improve existing infrastructure. These projects will cost $2.063 billion, and they plan to expand to existing water plants, additions to an existing balancing reservoir, and improvements to the filters at the water plants.

While Dallas' infrastructure is adequate, almost two-thirds of it is over 30 years old. Dallas is trying to solve its number one problem, aging infrastructure, by constantly replacing old parts of the water system. Dallas is also renovating and replacing various essential infrastructure, including water/wastewater treatment plants, pump stations, storage tanks, and piping.

As Dallas continues to supply clean water to its residents, something that is highly comforting is DWU's priorities. DWU prepares for the "worst-case scenario," said Denis Qualls. However, it is evident that Dallas is sufficiently controlling the water supply situation and is working on increasing the city's water supply to exceed projected demand through 2070.

Story John Householder
Illustration John Householder

Learning Through Another Pair of Eyes

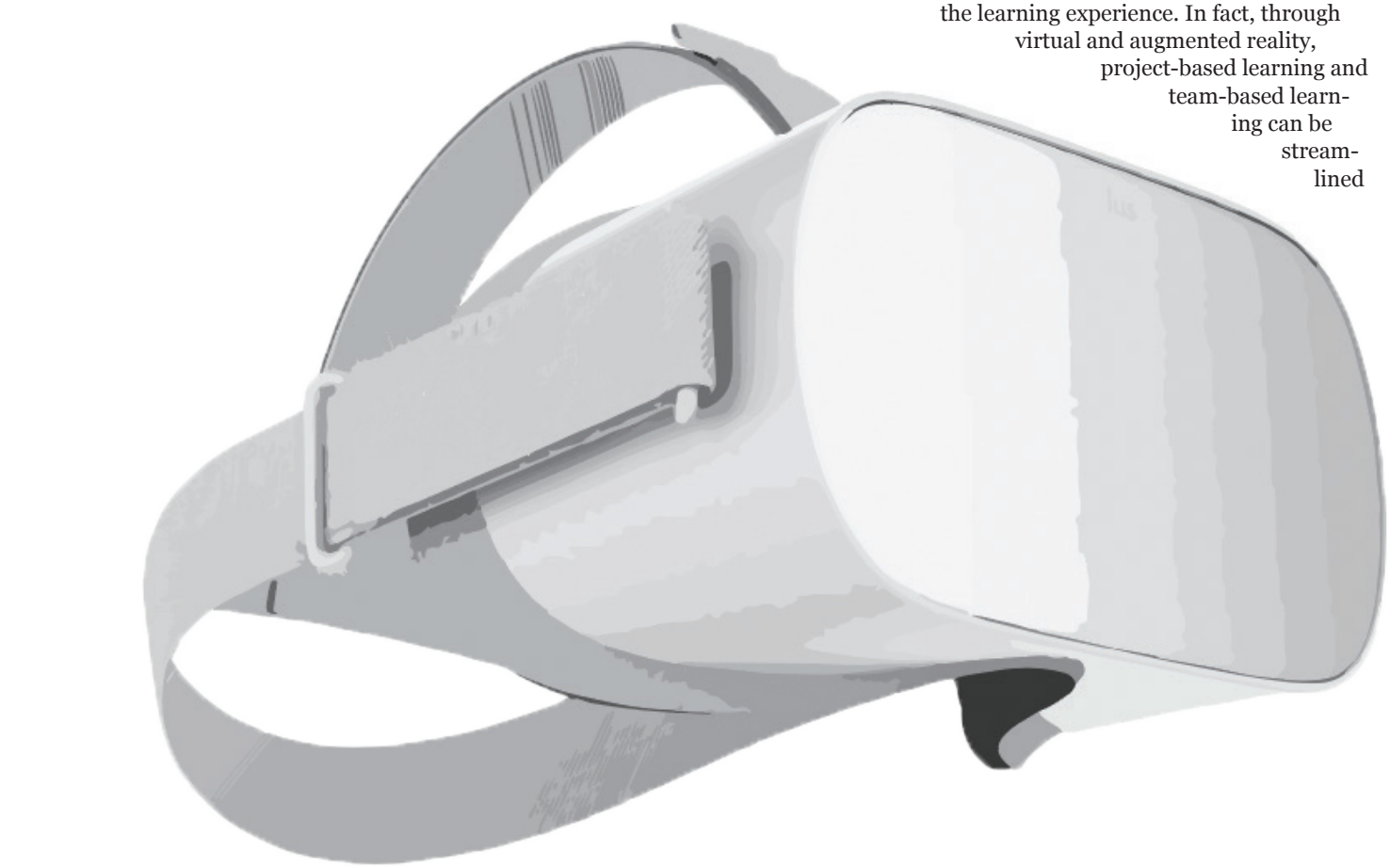
With VR and AR becoming a reality, schools are now applying this innovative technology to teaching.

Imagine that it's the first day of university. After weeks of shopping, packing, and last-minute errands, it's finally here: Orientation Day. But rather than traveling to campus for an in-person event, you are brought there from the comfort of your home. Without ever leaving your desk, you can explore the buildings, libraries, and other facilities. While it may seem like a fantasy today, the power of augmented reality and virtual reality technologies is making situations like these a reality in our rapidly evolving society.

After the pandemic struck a few years ago, students all around the country experimented with the idea of remote learning. While it had its advantages, it was mostly criticized as a poor replacement for conventional in-person instruction. With the implementation of VR and AR, that opinion might change. In fact, Stephen Gilbert, a professor of Virtual Reality and Human-Computer Interaction at Iowa State University, believes that VR will someday even replace in-person teaching.

"VR can be used to create gamified content that can engage students as they try to accomplish educational tasks in a virtual learning environment." Gilbert said.

For instance, VR can create a virtual lattice of DNA molecules that help students better understand the DNA helix. And even if there were not enough VR headset available for an entire class, asymmetric VR would still immerse the whole class into the learning experience. In fact, through virtual and augmented reality, project-based learning and team-based learning can be streamlined



and perfected down to a science.

"In asymmetric VR, the students' access to the virtual world is not identical, but each access mode can have advantages. For example, while it is hard to type in VR, someone on a different device might have a great bird's-eye view that could inform the headset wearer or be able to type out search queries. This collaboration that can happen in VR is very powerful. Companies use VR for purposes like this to bring in experts remotely." Gilbert said.

On the other hand, VR puts more work onto teachers to create their own virtual enivronment.

"It's not as easy as PowerPoint, and even with the latest current tools, the environment won't look as good as a video game, where game studios have millions of dollars to invest." Gilbert said.

Also, "cybersickness" could prevent a student from wearing a headset for a whole lesson's duration. Thus, students might need to take frequent breaks, which would break their train of thought and interrupt the learning process.

"Cybersickness is like motion sickness, but your body's not moving, and most people think it's caused by the conflicting inputs to your brain when the vestibular system in your ears is telling your brain 'You're sitting still' but the headset VR is making your eyes tell the brain, 'You're moving.' Not everyone gets sick. There are some people who never get cybersick. There are others who get sick just watching someone else play a 3D video game on a screen in the living room, let alone putting a headset on. As of now, we have found that many people will start to feel a little off if they wear a VR headset more than 30 minutes or so. And not only does cybersickness susceptibility vary enormously, but recovery time varies enormously also. Some people get a little queasy, then take off the headset, and they're fine. Other people might take off the headset and not feel normal for 6-8 hours. This is obviously a big problem, and one of the issues that's holding back VR. Many smart people are trying to figure out how to prevent cybersickness, and that's one of my top priorities right now." Gilbert said.

In spite of the challenges, the benefits of using AR and VR technology for collaboration in the classroom far outweigh the drawbacks. These technologies can enable students to work together on projects or assignments, regardless of their physical location. These virtual environments let students explore and interact with 3D models, simulations, and scenarios, which can enhance their understanding of complex concepts. Additionally, VR develop their teamwork skills by collaborating on projects and problem-solving tasks in virtual spaces. Ultimately, the integration of AR/VR technology in education will prove to be a game changer for students and teachers alike. Though the technology is still in its infancy, it has the potential to revolutionize the way students learn and engage with the world around them. As St. Mark's and other schools continue to integrate AR/VR technology into their classrooms, it will be exciting to see the new and innovative ways it will be used to enhance the educational experience.

Story Kevin Lu
Graphic Joseph Sun
Photo Joseph Sun

Virtual Learning In Computer Science instructor Kendell Murphy's class, Ward Beasley '29 hikes Mount Sinai though Virtual Reality

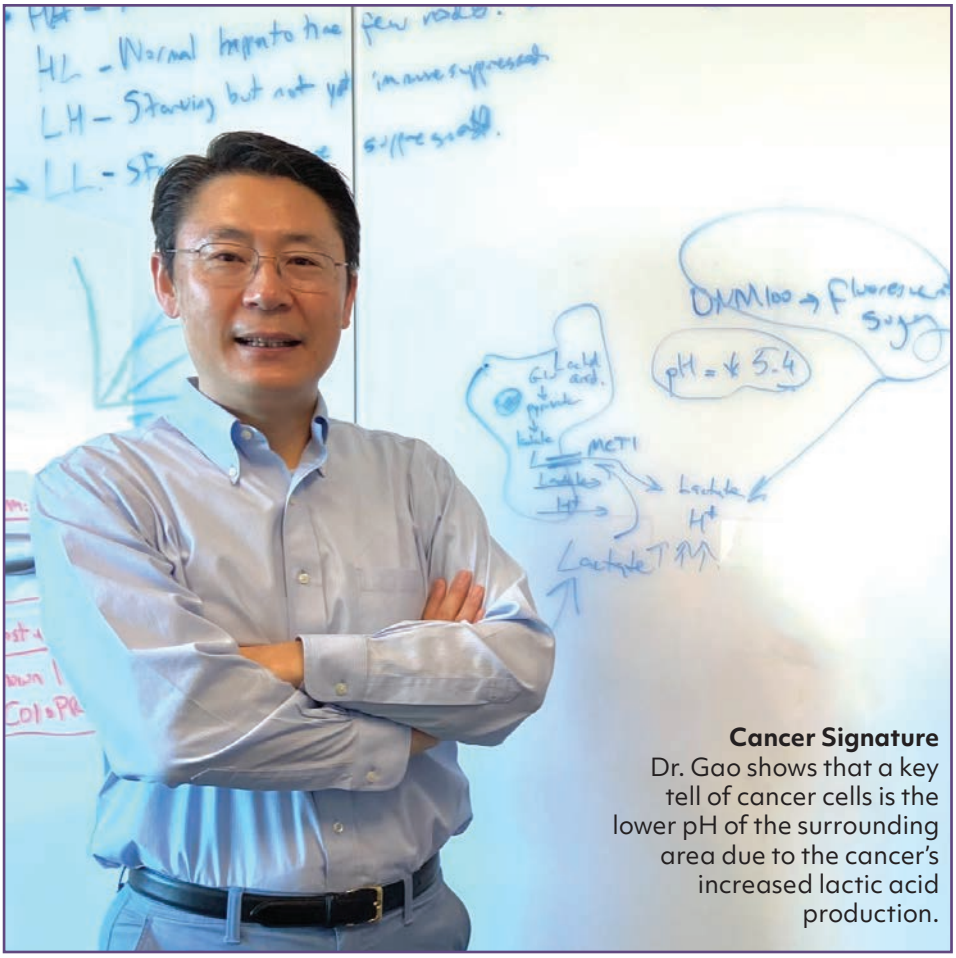
A STING Operation against Cancer

Instead of using external sources to fight cancer like chemicals or radiation, Dr. Jinming Gao aims to train our very own immune system with nanoparticles.

Im sorry, you have Stage 4 Cancer. If we had caught it sooner, maybe things would have been different.

These hollow words echoed from a physician once marked the end of a family, of a life, of a loved one. They once were a death sentence that left the patient speechless and shocked as his family clung onto him with teary eyes and faces scrunched in pure sorrow. Until now.

Dr. Jinming Gao, the Elaine Dewey Sammons Distinguished Chair in Cancer Research in the Simmons Cancer Center at UT Southwestern Medical Center, is now developing an ingenious way to combat against the disease. Instead of using radiation therapy or chemotherapy, Dr. Gao seeks to train the immune system, the body's own defenses, to take down cancer.



Cancer Signature
Dr. Gao shows that a key tell of cancer cells is the lower pH of the surrounding area due to the cancer's increased lactic acid production.

"As of right now, we are working on STING-activating nanoparticles for cancer immunotherapy. This invention has just received approval from the Food and Drug Administration to start first in human trials in 2023." Dr. Gao said.

STING stands for **ST**imulator of **IN**terferon **G**enes. It is part of an innate immune defense mechanism against viral infection or cancer formation in a cell. When foreign or tumor DNA is inadvertently released in cell cytoplasm, it triggers a danger signal and stimulates the synthesis of cyclic GMP-AMP, or cGAMP, a secondary messenger molecule. cGAMP then binds to STING, an endoplasmic reticulum-bound protein, which induces a cascade of inflammation and immune response.

"cGAMP-STING signaling is like an alarm system for the cell. Once foreign or its own DNA is detected inside the cytosol, the cell alerts the immune system that something is wrong. The immune system is then activated and responds with cytotoxic T cells, which seek out infected or cancer cells to kill them" Dr. Gao said.

Utilizing this alarm system, Dr. Gao's research group invented a unique pH sensitive nanoparticle not only as a carrier for cGAMP but also activate STING in a synergistic fashion. By injecting these nanoparticles into specific reigions of the body, Dr. Gao has the power to activate an immunal response anwhere, including inside tumors that have suppressed the immune system.

"The reason why cancer is difficult

to cure is because it can hide itself well from the immune system. Cancer is able to suppress the immune system by lowering the pH in the area and tricking macrophages into suppressing cytotoxic T cells in that area. Thus, it becomes 'cold' in the immune surveillance sense." Dr. Gao said.

With these nanoparticles, Dr. Gao can now render these tumors "hot" and counteract the cancer's suppression of the immune system.

"How it works is that once the nanoparticles are injected inside a tumor, macrophages and dendritic cells nearby, although suppressed by the cancer cells, will engulf these nanoparticles as foreign objects through endocytosis. Once inside the endosomes, the organelle pH will drop, which will dissociate the pH sensitive nanoparticles into cationic polymers and free cGAMP. The cationic polymer disrupts endosomal membranes that causes the escape of cGAMP and the cationic polymers into the cytosol, which both activate STING." Dr. Gao said.

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With STING now activated, the dendritic cell's alarm systems go off. The dendritic cell releases cytokines to call for more dedritric cells into the region, overcomes the cancer's suppression, and now engulfs the antigens of the cancer cells for processing.

"Then, the dendritic cells travel to the lymph nodes where they will activate the naive T cells to make antigen-specific T cells. Once the antigen-specific T cells are made in the lymph nodes, these T cells travel back

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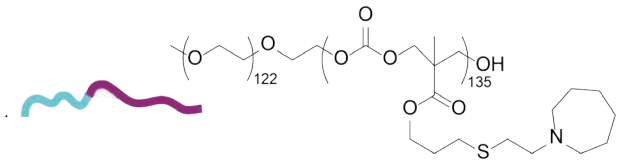
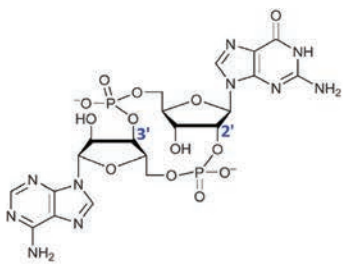
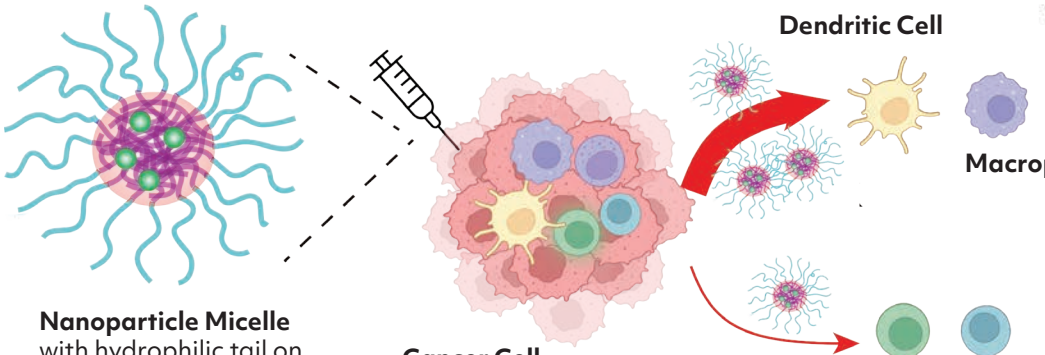
PSC7A
Shown here is a strand of the nanoparticle micelle. The purple part is hydrophobic while the blue part is hydrophilic. Chemical structure is shown on the right.



cGAMP
Cyclic guanosine monophosphate–adenosine monophosphate is labeled here as a green dot. The chemical structure is on the right. It is the activator of STING.





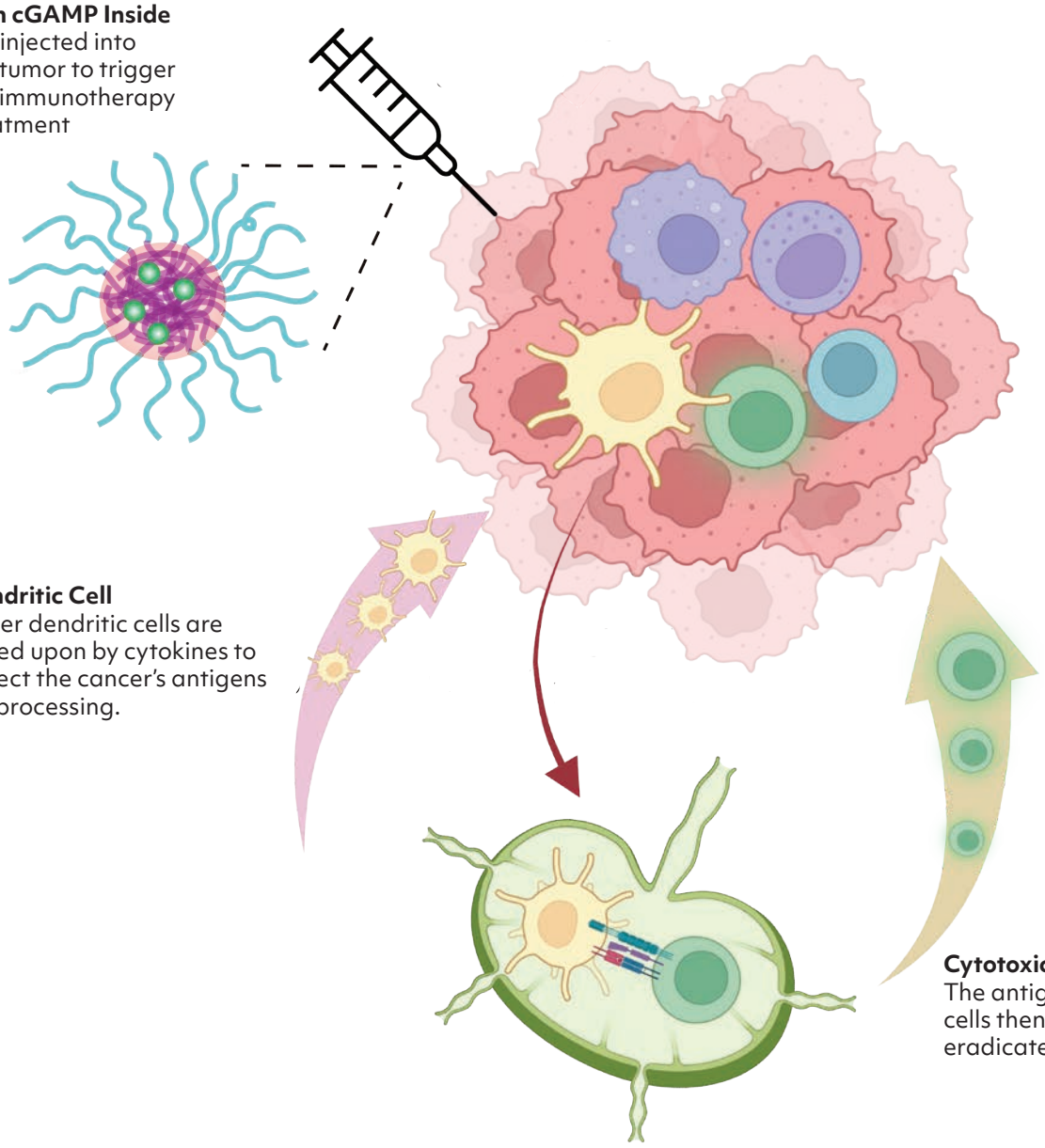
Nanoparticle Micelle
with hydrophilic tail on the outside and hydrophobic head on the inside. cGAMP in green is inside.

Cancer Cell
The cancer cluster is labeled in pink. The conglomeration shows a malignant tumor with unrestricted growth.

Plan of Attack
When the nanoparticle micelle is injected into the tumor cluster, it will activate nearby dendritic cells and macrophages. The dendritic cell would then travel to a nearby lymph node to train naive T cells and B cells to become antigen-specific to the cancer. Then, all four types of cells would eradicate the cancer conglomeration.

Close up of the Attack
The diagram now shows in more detail how the nanoparticle-activated dendritic cell recruits more dendritic cells to collect more cancer antigens and how the dendritic cells train naive T cells in the lymph node. Once the T cells are trained, they soon infiltrate the cancer cluster and eradicate it ruthlessly.

Nanoparticle Micelle with cGAMP Inside
It is injected into the tumor to trigger the immunotherapy treatment



Dendritic Cell
Other dendritic cells are called upon by cytokines to collect the cancer's antigens for processing.

Cytotoxic T Cells
The antigen-specific T cells then inflitrate and eradicate the cancer cells.

Lymph Node
Dendritic cells arrive to the lymph node and train naive cytotoxic T cells to became antigen-specific to the cancer.

to the tumor to kill the cancer cells." Dr. Gao said.

As for macrophages, the same process happens. But instead of going to the lymph node and training naive T cells like the dendritic cell, it stops its suppression of the immune system and instead causes more inflammation and immune activity.

But to keep the nanoparticle from spreading into healthy cells, Dr. Gao made his nanoparticles hydrophilic enough to spread throughout the tumor but large enough to prevent it from washing out into the blood stream.

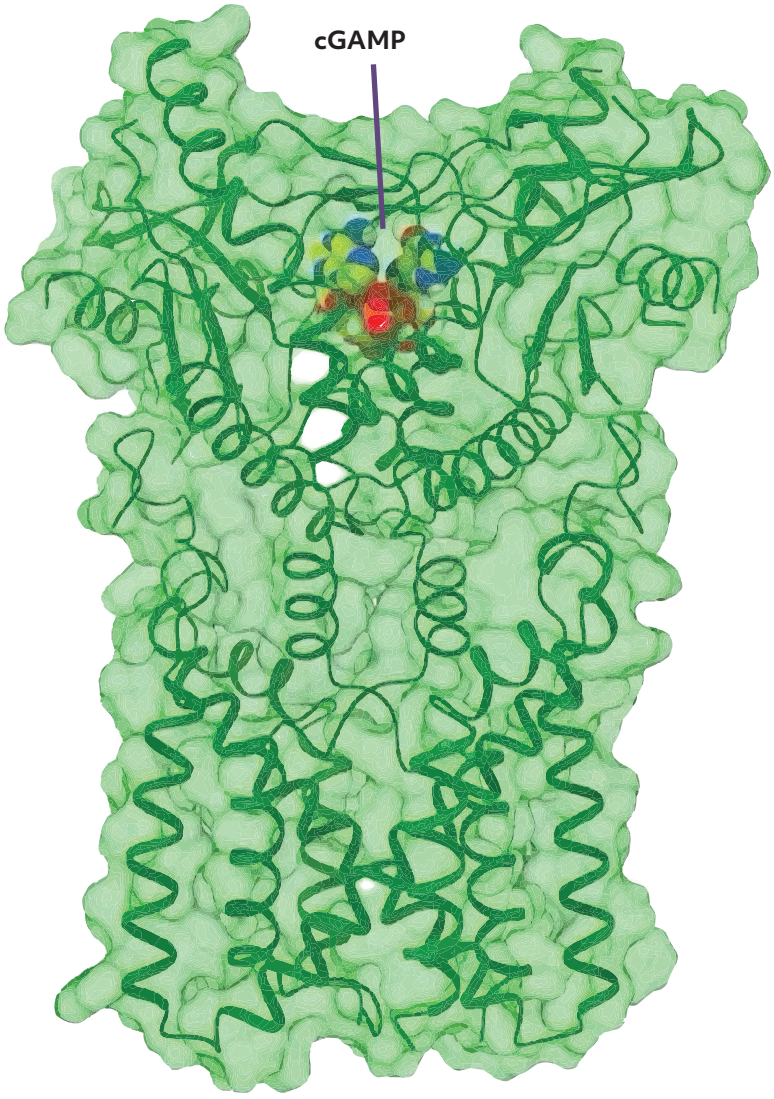
"The nanoparticle shell increases tumor retention. We have found that when injecting cGAMP into a tumor site, it ends up perfusing out of the tumor and entering blood circulation, causing a high level of systemic cytokines by spreading into healthy parts of the body. This could result in a cytokine storm, doing more harm than good. Our nanoparticle does not perfuse out of the tumor as quickly or as much. Although like cGAMP, it is hydrophilic, but it's also a million times larger than cGAMP. It is well suspended in fluid where it can travel inside tumors but not enter blood vessels and distribute throughout the body. If we had made the nanoparticle hydrophobic, it would aggregate with itself and become less useful. So the whole process was like walking on a tight rope. We want it to spread throughout the tumor but not too much to the point where it spreads throughout the body." Dr. Gao said.

The nanoparticle structure also prevents patrolling T cells from taking in cGAMP and committing suicide.

"This isn't set in stone right now, but many papers talk about the duality role of cGAMP in immune protection. Turns out, cGAMP galvanizes the dendritic cells and macrophages, but they also kill T cells when T cells internalize them. Thus, the nanoparticle structure serves another purpose. T cells will usually take in cGAMP through membrane transport, but because of the sheer size of the nanoparticle, that is now impossible. The nanoparticle can only be taken into the cell through endocytosis, which macrophages and dendritic cells, not T cells, do." Dr. Gao said.

Although still far from commercial use, Dr. Gao's STING-activating nanoparticles hold great promise. Unlike radiation or chemotherapy, which have only been around for several decades, the immune system has been fighting off infection and cancer since the dawn of time. It has been perfectly calibrated and trained to discern cancer cells from healthy ones with brutal efficiency. Thus, instead of looking for external sources to cure cancer, patients only need to look inside. There is already a system in place for thousands of years trained to fight cancer. All it needs is a little help.

Story Michael Gao
Image Courtesy of Dr. Jinming Gao
Graphics Courtesy of Dr. Gang Huang (left and page 63) and Dr. Xuewu Zhang (down)



Cryo Electron Microscopic Image of STING Protein Interacting with cGAMP
In green, STING changes its shape when binding with cGAMP.

Closing

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Details

Policy

The Scientific Marksman is an out-of-school extracurricular activity that works independently from the St. Mark's School of Texas journalism program. Throughout the first half of the year, staff members pitch story concepts, hold interviews, and write articles; the majority of the design process occurs in the latter half. This publication is submitted annually for evaluation to the Columbia Scholastic Press Association (CSPA) and the National Scholastic Press Association (NSPA)

Colophon

The Scientific Marksman is printed by Digital 3 Printing. The cover is 100# Polar Bear Velvet Cover printed 4/4 in four color process inks. Text is 100# Polar Bear Velvet Tex printed 4/4 in four color process inks. Binding is PUR glue perfect binding. The Staff uses Adobe InDesign, Illustrator, and Photoshop 2023 on 27-inch Retina 5K Display iMacs and a 13-inch 2013 Macbook Pro to design the spreads. Typefaces include Khmer MN for headlines; Objektiv Mk1 for subheadings, pull quotes and bylines (multiple weights and styles); and Georgia for body text and folio.

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