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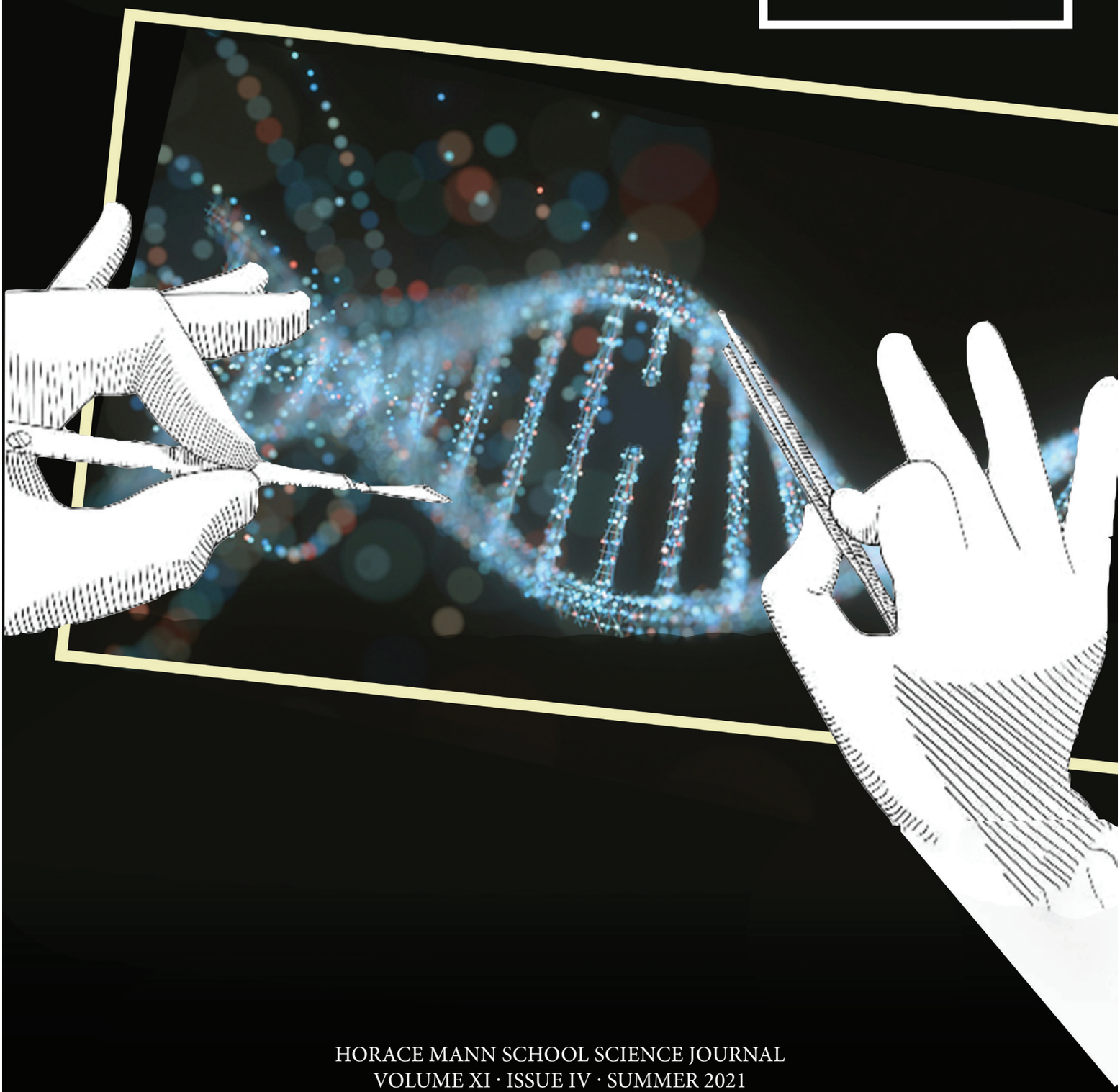

HORACE MANN SCHOOL SCIENCE JOURNAL
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LETTER FROM THE EDITORS

Dear Readers,

Each year, as new research is released, ethics becomes more intertwined with science. Questions of what subjects should be researched, what procedures can be used, and how results are interpreted have become moral ones just as much as they are scientific. Bioethics, a discipline that studies these philosophical questions and their impacts on modern scientific study, has become increasingly important since the term was coined less than 100 years ago.

The advent of the legally-mandated Institutional Review Board to monitor all biomedical research involving human subjects and the ongoing debates regarding topics such as end-of-life care, medical resource allocation, organ donation, and environmental ethics are just a few examples of the wide-ranging impacts of bioethics on society. As more food becomes sourced from GMOs (genetically modified organisms), medical records become computerized, and healthcare disparities persist, the domain of bioethics grows larger with each new paper published.

This issue's Features topic explores bioethics and its ramifications as they will continue to manifest in a future society. Articles focus on agriculture ethics and genetic modification of crops, the debate surrounding assisted reproductive technology, and moral arguments relating to recently-popularized genetics kits.

In addition to the Features section, this issue showcases articles in Biology, Chemistry, and Physics focused on the new COVID-19 vaccines, innovative experiments and uses for batteries, and recent breakthroughs in nuclear fusion, respectively.

We would like to extend our most sincere gratitude toward all of the writers and editors who contributed to this final issue of the school year. We are also deeply appreciative of Spectrum's faculty advisor, Dr. Christine Leo, and would like to thank her for her consistent support, guidance, and advice.

Sincerely,

Danielle Paulson

Sam Singer

Danielle Paulson
Editors-in-Chief, Volume XI

Sam Singer

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Genetic and Medical Data Privacy

Purvi Jonnalagadda

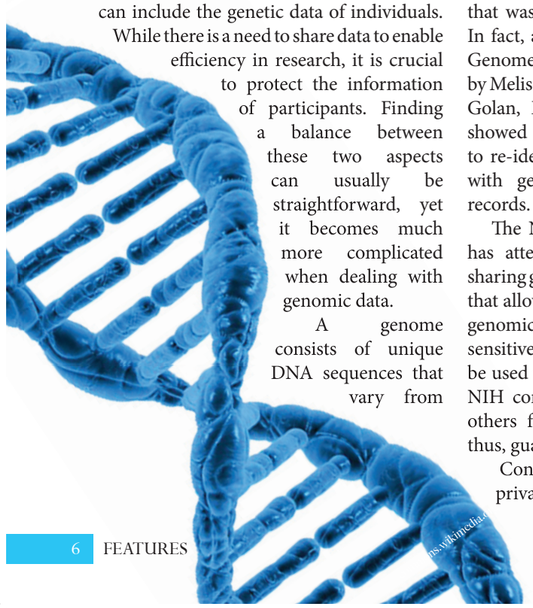
Staff Writer

Each human has a unique set of genes, acquired from the combination of their parent egg and sperm cells. One's genetic data contains information about these inherited genes, which can then be understood by analyzing a sample of one's DNA or RNA. The sequencing of genes is beneficial in identifying the risk of certain diseases and disorders, one being diabetes. However, when scientists conduct research on one's genome, or complete set of genes, the compiling and sharing of this information raises questions of privacy. As part of the scientific community, researchers often share their findings with one another for scientific betterment. This information can include the genetic data of individuals.

"A DNA SAMPLE IS NEVER COMPLETELY ANONYMOUS AND PRIVACY WITH A SAMPLE IS NEVER GUARANTEED."

While there is a need to share data to enable efficiency in research, it is crucial to protect the information of participants. Finding a balance between these two aspects can usually be straightforward, yet it becomes much more complicated when dealing with genomic data.

A genome consists of unique DNA sequences that vary from person to person. Thus, a DNA sample is never completely anonymous and privacy with a sample is never guaranteed. It is also important to note that DNA can be acquired from a person's saliva, blood, hair, and other tissue left on surfaces. As a result, one's genetic data can be easily obtained, even without one's knowledge or consent, escalating the need for genetic data privacy. The Health Insurance Portability and Accountability Act (HIPAA) and the Genetic Information Nondiscrimination Act (GINA) have tried to limit access and ensure privacy with data about genetic data and DNA information, but methods such as genotype-phenotype inferences and family structures can be used to re-identify the data that was supposed to be kept anonymous. In fact, a 2013 study, "Identifying Personal Genomes by Surname Inference," conducted by Melissa Gymrek, Amy L. McGuire, David Golan, Eran Halperin, and Yaniv Erlich, showed that genomic data could be used to re-identify participants when compared with genealogical databases and public records.



The National Institute of Health (NIH) has attempted to minimize the risks of sharing genomic data by providing databases that allow researchers to share de-identified genomic data. These databases also manage sensitive information that could possibly be used to re-identify a participant, but the NIH controls the information, preventing others from identifying participants, and thus, guaranteeing privacy.

Concerns regarding genetic data privacy first emerged with the 1990 Human Genome Project. Prior to the project, its planners anticipated the exploitation of genetic information. In response to concerns, the Ethical, Legal, and Social Implications (ELSI) Working Group was founded in 1989. Made up of genome scientists, medical geneticists, law, ethics, and philosophy experts, and consumers, this group foresaw that studies involving the location of diseases on chromosomes could be used by insurance companies to create a list of genetic risk factors and deny insurance to people with those diseases. Afraid that discrimination against these individuals would result in a lack of access to health insurance, the ELSI Working Group publicly supported GINA, which was introduced into law in 2008. GINA forbids employers from hiring, firing, promoting, and deciding compensation based on genetic information. It additionally prohibits insurance companies from requiring people to submit genetic tests, denying coverage, or discriminating against people based on their genetic information or family history.

Despite this legislation, many still fear genetic discrimination, and their trepidation is not baseless. Learning about one's family ancestry is a new interest among a majority of people. This has led to the creation of companies such as 23andMe. Essentially, consumers use an at-home genetic test to send a saliva sample which the company then tests. The ancestry report is usually created by comparing the user's saliva to the company's databases. In other words, the results are arbitrary. Yet, the most surprising aspect of these companies is that they make revenue through selling the data from genetic tests. Leading up to 2017, 23andMe gave thirteen pharmaceutical companies access to their databases. While the pharmaceutical companies use the genetic information for research and other experimentation, such as determining what makes a person more likely to be diagnosed with a disorder, customers did not consent to providing pharmaceutical firms with their genetic data. These actions bring up the questioning of ethics in such practices. Thus, in 2018, genetic testing companies began considering consumer privacy and claimed they would require a customer's consent before using their genetic data for any other purposes.

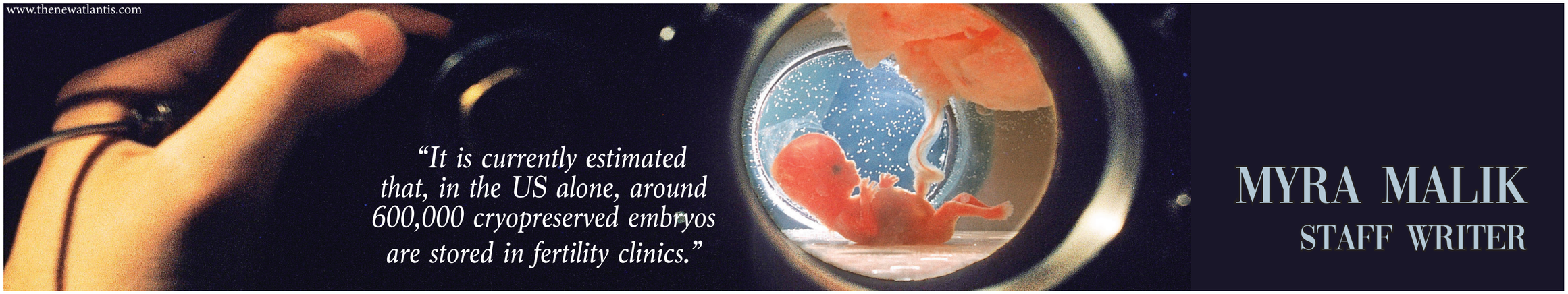
Moreover, as new technology is developed, the documentation of people's health care records has become digital. This information is referred to as medical data and is stored in electronic health records (EHRs). EHRs also track patients' demographics, conditions, progress, and treatments. This shift from physical to digital took place per HIPAA. However, this law was created before technological advances. As a result, medical data is much less secure than genetic data; it simply is not protected. For instance, health apps and fitness gadgets, such as Fitbits or Apple watches, collect one's health data and use this data for a variety of reasons including advertisement purposes. Many such apps share users' de-identified data with third parties, without the user's knowledge or consent. Yet, this de-identified data can easily be re-identified with certain techniques, such as utilizing public information about demographics, gender, age, etc. and comparing it to de-identified genetic data. Many apps also use the policy that if a customer uses an app, they consent to sharing their data, but many users are unaware of this aspect since it is common to overlook the privacy policy.

"MANY SUCH APPS SHARE USERS' DE-IDENTIFIED DATA WITH THIRD PARTIES, WITHOUT THE USER'S KNOWLEDGE OR CONSENT." YET, THIS DE-IDENTIFIED DATA CAN EASILY BE REIDENTIFIED."

The argument for the ability to identify patients from their DNA comes from scientists claiming that genetic data actually helps researchers determine useful information about the causes and risks of diseases, drug discovery, and neurological developments such as cognition and psychiatric disorders. In other words, identifying the participants behind the genetic data can be useful to scientists as they will have more information about the participants which can help with research.

While there are worries of genetic information protection, individuals can keep their data private. One such way is data masking, the process of creating a fake version of one's data. Data masking prevents scientists from knowing personal data while simultaneously providing them with enough information needed to appropriately serve as an alternate. The main purpose of data masking is to prevent data re-identification and can be done by changing the order of numbers or characters in the data being hidden. Gene masking, a process similar to data masking, is more relevant to privacy with genetic information. This method uses a binary coded genetic algorithm that forms a template representing a chromosome. In other words, scientists are provided with a masked version of one's chromosomes which cannot be re-identified.

Currently, any rules put in place to protect genetic and medical data will most likely become quickly outdated due to rapid technological advancements. Especially in a future of smart homes, mirrors that reveal skin and heart conditions, and devices that monitor one's health, maintaining privacy is crucial. The government needs to enforce laws that will protect peoples' identities, updating them following new technological advancements. Furthermore, people should also have a right over their digital data and be able to change or delete their data, and determining this control over data was not highly debated until recently. This new concern arises with the development of new technologies that allow scientists to come to more complex conclusions by analyzing DNA. If this information is not kept private, insurance agents can underwrite claims, lawyers can use the data as evidence to defend themselves or prove the other party guilty, or law enforcement officials can attempt to distinguish suspects or mass attack victims without consent. Ultimately, the debate over genetic and medical data privacy must be more focused on as technology develops and new methods to obstruct one's privacy arise.



MYRA MALIK
STAFF WRITER

MODERN ASSISTED REPRODUCTIVE TECHNOLOGY

Assisted reproductive technologies (ART) have received mass attention from the general public since their debut in the late 20th century, from the world of science to that of ethics. Since its invention, ART has helped infertile individuals reproduce with a hand from technology.

Those facing complications with fertility now have a range of options for reproduction. Outside of ART, some treatments for infertility in biological women are hormone medications to promote ovulation, surgery for blocked or damaged fallopian tubes, laser treatment or medication for endometriosis, and artificial insemination. Treatments for biological men include retrieval for artificial insemination or improving diet and lifestyle. Should one not wish to treat the underlying cause of infertility, or if the cause's severity is too great – such as with extreme endometriosis, for example – they could use ART.

The most common and effective form of ART is in vitro fertilization (IVF). IVF is a technology through which a biological woman receives fertility drugs to produce more eggs and fertilization takes place within a petri dish. The first infant conceived via IVF was Louise Brown, born in 1978. IVF may also be combined with ICSI, intracytoplasmic sperm insertion, which pertains to sperm producing individuals with low sperm counts. If fertilization occurs in the petri dish, the embryo is then implanted in the lining of a biological woman's uterus a few days past fertilization. It has become popular to use multiple embryos in hopes that at least one will begin to develop normally; however, there is a risk of multiple embryos developing, resulting in multiple births. This can endanger the birthing person, due to increased stress during labor, and to the children, due to increased risk of low birth weight.

While 99% of all ART used is IVF, other forms of ART include gamete intrafallopian transfer (GIFT), zygote intrafallopian transfer (ZIFT), and frozen embryo transfer (FET). GIFT removes the individual gametes and mixes them in the fallopian tube directly, allowing them to fertilize in the tube–instead of in a petri dish such as in IVF. This method is less popular because biological women with damaged fallopian tubes may not use it, and the doctor cannot visually confirm the health or success of the embryo. ZIFT is similar to GIFT, but it transfers an already-formed zygote instead of the individual gametes. ZIFT is less popular than IVF because it takes longer and can be more expensive. Finally, FET is very similar to IVF, but it uses a frozen embryo from a previous IVF attempt. FET is gaining popularity because it avoids desynchronization in the menstrual cycle. During typical IVF, progesterone may increase too early to create an ideal environment for development, because the ovaries are artificially stimulated to collect eggs. While medication is available to suppress progesterone production in IVF patients, it does not work in every patient. Therefore, FET avoids desynchronization by allowing the patient to wait until their hormone levels are ideal before a doctor implants the embryo.

Very few individuals opt to donate their embryos, for emotional and ethical reasons around their genetic material going to another patient. Furthermore, situations complicate further in cases of divorce or death of a parent.

Considering the facts about the types of ART and their popularity, what are the downsides? Multifetal pregnancy is a common, yet sometimes dangerous, outcome of ART, affecting almost half of all ART pregnancies. Single-embryo transfer is recommended to avoid this outcome, but it is not always the most cost-effective or time-efficient option, as it may take a long time for a viable baby to develop. Other less common risks include prematurity, preeclampsia (abnormally, and sometimes fatally, high blood pressure as a pregnancy complication), and birth defects.

There is also a notable debate around the ethics of assisted reproductive technology. The largest issues include embryo selection, financial ability, and lack of oversight. Embryo creation, selection, and disposal is a major issue for fertility clinics performing IVF. It is currently estimated that, in the US alone, around 600,000 cryopreserved embryos are stored in fertility clinics. Ethical and legal concerns cause hesitancy around simply disposing of the embryos without the patient's consent. Very few individuals opt to donate their embryos, for emotional and ethical reasons around their genetic material going to another patient. Furthermore, situations complicate further in cases of divorce or death of a parent.

The financial debate stems from the deregulation of fertility clinics in the US. The average cost of one IVF cycle is $12,400, and many patients need more than one round before a successful pregnancy. Additionally, only 15 states have laws around insurance companies having to cover ART procedures, discouraging poor or uninsured biological women from seeking these treatments. Finally, lack of oversight causes multiple problems in the processes of ART. Therefore, practitioners may make unfair or dangerous judgements in accordance with their own beliefs rather than in accordance with the law. Avoiding public discussion around legally regulating ART procedures causes many debates and potentially dangerous outcomes.

Although ethical debates play a large role in discussions around ART, the treatment itself is becoming safer. The main issues with ART stem from premature and multiple births, and research is still needed into the effects of IVF on the baby as it grows. While it continues to improve, ART provides the opportunity to millions of people struggling with infertility to reproduce safely.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Approaching a Genetically Modified Agricultural Future

By Daniel Schlumberger
Staff Writer

One of the greatest environmental challenges scientists have faced in the 21st century is the genetic engineering of plants and animals. In the past, humans have used traditional cross-breeding techniques to breed plants and animals with desirable traits. After scientists developed genetic engineering in the 1970s, similar changes could be made with more precision and in a shorter period of time. Genetic engineering allowed scientists to splice or cut and replace specific genes that exhibit certain traits and add them to crops for various reasons, improving qualities such as crops's overall growth, nutritional content sustainability, tolerance to drought, and pest and disease resistance. In fact, most of the food people eat on a daily basis has experienced some form of genetic alteration. According to the U.S. Department of Agriculture (USDA), genetically modified seeds are used to plant more than 90% of corn, cotton, and soy in the country. Furthermore, the Center of Food safety labeled that genetically modified (GM) ingredients are contained within over 70 percent of processed foods. Newly modified genetic technologies could also be highly beneficial as a reduction in agrichemical use would reduce the carbon footprint. Although genetically modified organisms (GMOs) provide many opportunities for agricultural improvement, their widespread application raises ethical questions.

What is the process to create a GMO and how do scientists actually modify organisms to get improved qualities within crops?

stocksnap.io

The process starts when a scientist inserts a selected gene into the DNA of the nucleus of a single cell. The DNA strand being used is so small that it's not visible to the eye, even under a powerful microscope. Despite its size, massive amounts of DNA are packed within this nucleus. The altering is done by removing or adding a gene or altering a few base pairs through natural or artificial gene modification systems. Once modified, the scientist will treat it with naturally occurring plant hormones to stimulate growth and development.

"Most of the food we eat on a daily basis has experienced some form of genetic alteration."

On March 19, 2021, the European Group on Ethics in Science (EGE) released a report investigating the status of newly developed genomic techniques under the European Union law. The opinions outlined in the study analyzed the ethical questions that have emerged from the application of new genome techniques (NGT) on plants, animals, agri-food, and micro-organisms. Many of the ethical concerns that have been raised about GM crops include: potential harm to human health; potential damage to the environment; negative impact on traditional farming; excessive corporate dominance; and the unnatural aspect of the technology. The general consensus, however, has been that the risks of GMOs should be weighed against their benefits as well as the risks of alternative options. The study identified the limitations within NGT legislation that can emerge challenges to keep up with scientific developments. In their report, the EGE indicated that the current legislation is ill-equipped for the purpose of some NGTs and that adaptation will be required in the future to accommodate scientific and technological progress. Furthermore, the EGE claimed that genome editing could in fact be highly beneficial in ensuring food security and reducing the impact of agricultural practice on the climate. They concluded that the EU should accelerate the adoption of plant genome editing to keep pace with international competition and encourage further support for food production.

The implementation of gene editing within plants would also bring the EU closer to reaching its goals of Farm-to-Fork Strategy,

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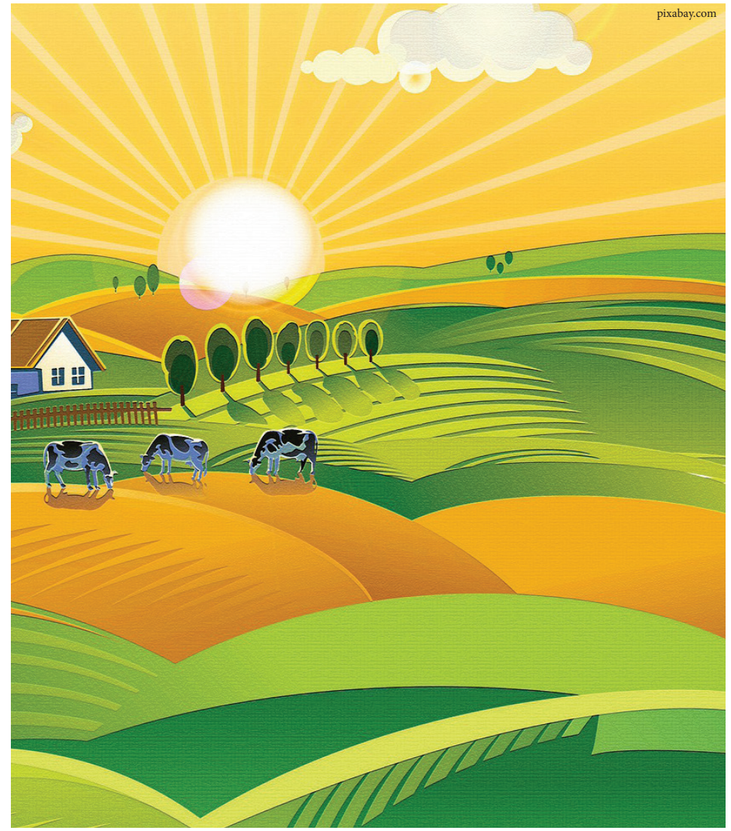
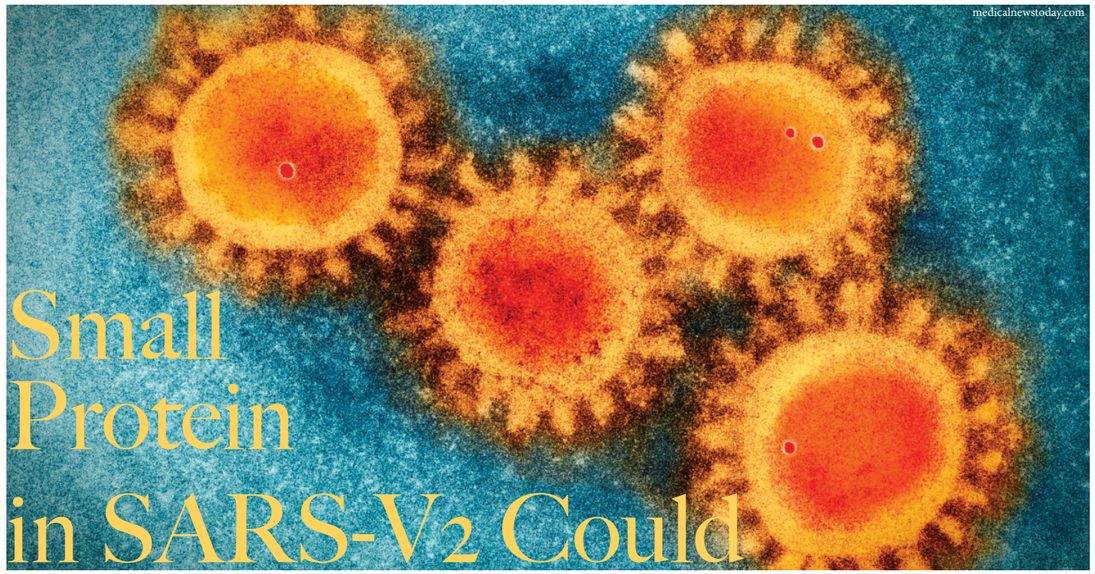


aiming to redesign the current food systems for a more sustainable future. According to the European Commision, their goal by 2030 will be to reduce fertilisers by 30 percent and turn 25 percent of agricultural land over to organic farming. Precision genome editing, a process where scientists make precise changes in an organism's DNA at precise locations and make changes without leaving behind additional foreign DNA sequences, was ruled out in 2018 by the European Court of Justice, claiming the technologies to be against the 2001 EU directive banning of genetically modified organisms. However, British industries, post-Brexit, are considering applying gene editing in crops and agriculture. The British government's point of view on the case claims that organisms subject to gene editing and gene technologies should not be viewed as GMOs if already produced by current breeding methods. Argentina, alongside other countries such as the US, Canada, Japan, and other South American countries have already applied gene editing techniques in agricultural fields.

"Although GMOs provide many opportunities for agricultural improvement, their widespread application has raised ethical questions."

Ethicists also called for more inclusive societal debate on genome editing, to have more influence over future scientific developments and to establish a system of global governance of gene editing strategies. Oana Dima, a science policy manager at EU-SAG, a scientific advisory group of over 134 European plant science institutes advocating for the use of genomic techniques, said "For the moment, Europe is lagging behind." Many figures within the scientific community like Dima have looked forward to the report, hoping that it could be the key factor to push for a greater acceptance of gene editing technologies.

Biology



Small Protein in SARS-V2 Could Provide Treatments for Coronavirus Strain Variants

Leah Sepiashvili
Staff Writer

Since early March of 2020, the media has been filled with ever-updating reports on the COVID-19 pandemic. Although the average American now has a plethora of COVID-19 vaccines to choose from, the death tolls worldwide are still rising. As the coronavirus spreads and continues to infect large communities of people, mutations leading to strain variants across Europe, South Africa, India, South America, and the United States continue to appear and raise the global death count.

Vaccines–administered to the general population as early as December 2020–provided relief and protection against COVID-19 throughout the world. Within the United States, there are three vaccines authorized by the FDA: Pfizer, Moderna, and Johnson & Johnson. While they have all been administered, some have proved more effective than others. Pfizer and Moderna are the most effective vaccines on the virus' original strain, with efficacy rates of around 95%. Johnson & Johnson had overall efficacy rates of about 72% and Astra-Zeneca, a vaccine unavailable for use in the US, has an efficacy rate of 76%.

While these vaccines are effective for the original strain, their effectiveness decreases as the coronavirus strain mutates. Meaning, the farther away from the original strain the variant shifts, the less effective the vaccine is after being administered. This ineffectiveness is because vaccines like Pfizer and AstraZeneca are specifically designed to protect against the SARS-CoV-2 protein–also known as the Spike protein–located on the viral membrane, the part of the virus that is exposed to the external environment. The Spike protein can attach to host cells through receptors on the cell membrane, allowing the virus to inject its own DNA into the host and begin its invasion. As it is located out of viral membrane, the Spike protein is subject to mutations through environmental factors that allow for external "tampering," thus changing its structure more rapidly and resulting in the variants that have appeared worldwide.

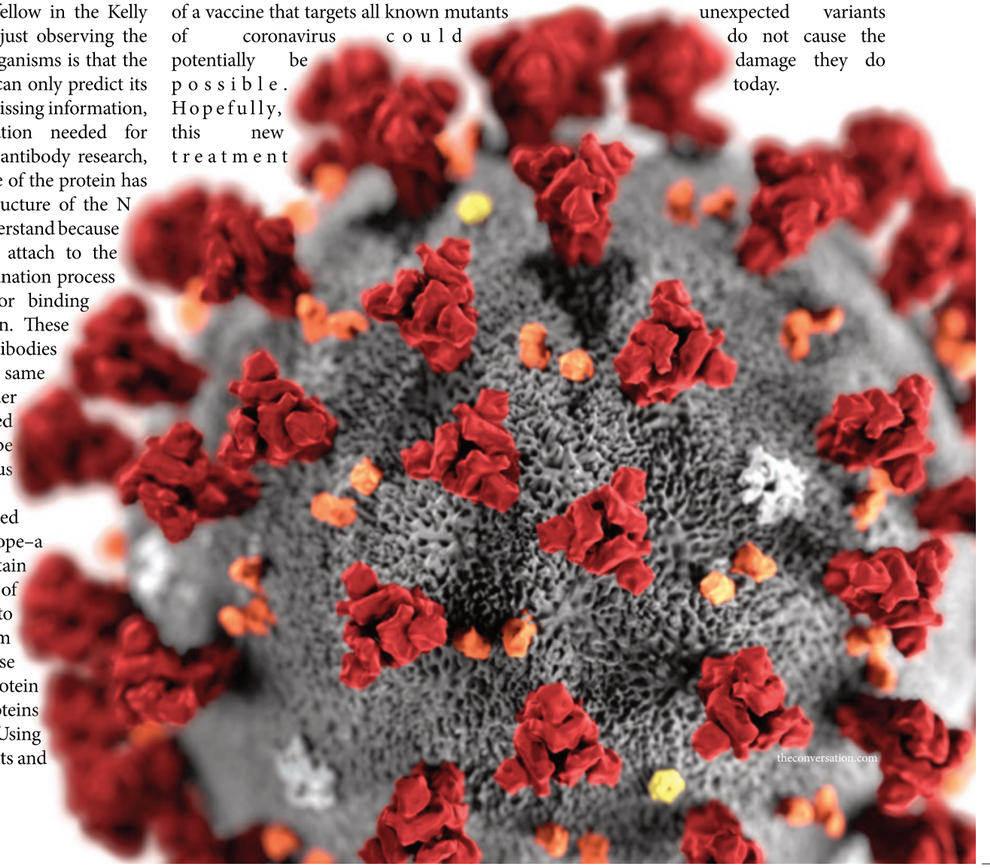
Despite the Spike protein's ability to rapidly mutate, there is hope of a new vaccine approach that may be more effective than current vaccines in fighting against coronavirus variants. A recent study, directed by Dr. Deb Kelly, professor of biochemical engineering at Huck Chair and director of Penn State's Center for Structural Oncology, has found the first complete structure of the Nucleocapsid (N) protein. Unlike the Spike protein, the N protein is found inside the virus. Thus, is protected from environmental pressures that would cause it to mutate. The N protein encases the viral genome and is fundamental for the replication of its RNA. In addition, the SARS-CoV-2 N protein is produced at high levels inside infected cells, becoming a good indicator of previously infected patients and the presence of antibodies. Once the N protein releases the viral genome and is no longer needed, it is exposed to the blood and floats without restraint through the bloodstream. The freed protein is also what causes an extreme immune response in patients and is the catalyst to the production of antibodies made to fight against the coronavirus. Kelly's study observed how antibodies from previously infected patients interacted with this protein. Most importantly, their research found that the N protein maintains a similar structure across all tested variants of the coronavirus.

In order to determine the structure of the N protein across coronavirus strains, the Kelly Lab looked at the N protein sequences found in humans and other animals thought to be sources of the pandemic such as bats and pangolins. Although the N proteins looked similar in structure, they did have distinct differences, according to Michael Casanta, a predoctoral fellow in the Kelly Lab. The problem with just observing the N protein in different organisms is that the sequence of the protein can only predict its structure. To get all the missing information, especially the information needed for vaccine production and antibody research, the accurate 3D structure of the protein has to be identified. The structure of the N protein is essential to understand because an antibody's ability to attach to the virus and begin the elimination process depends on the exterior binding sites of the viral protein. These activation sites for the antibodies need to be precisely the same for every N protein in order for a vaccine targeted towards the N protein to be effective for all coronavirus strains.

The researchers used an electron microscope–a microscope used to obtain high-resolution images of biological specimens–to work around this problem and capture more precise pictures of both the N protein and the sites on the N proteins where antibodies bind. Using both samples from patients and computer models, the researchers created a 3D model of the protein's structure. Kelly and her team were then able to find that the antibody binding site in the N protein was the same across all known variants.

Where standard COVID-19 diagnostic tests look for the Spike protein to determine whether the patient is currently infected, antibody tests search for the N protein to tell if the patient has already been infected. The team's findings are crucial because antibodies are made to fit to binding sites that a specific antigen (foreign body) has. The discovery of similar binding sites across coronavirus strains is especially important because it allows for similar antibodies to bind to most coronavirus strains–original or mutated. Furthermore, it means that the possibility of a vaccine that targets all known mutants of coronavirus could potentially be possible. Hopefully, this new treatment strategy can significantly reduce the number of people infected and transmitting the virus. Suppose new medications targeting the N protein binding site are made. In that case, these treatments could drastically diminish the lasting immune responses to COVID-19, especially for people who still have COVID-19 symptoms for six or more weeks after their infection. The possibility of an all-encompassing treatment means that unexpected variants, like the ones in India and the UK, would have no effect on the efficacy of vaccines made to target N proteins. Although the pandemic still continues to affect lives worldwide, the studies on N proteins have the potential to eradicate the threat of new coronavirus strains and create a more optimistic future where new and unexpected variants do not cause the damage they do today.

> "It means that the possibility of a vaccine that targets all known mutants of COVID-19 could potentially be possible."



Impact of Vaccination on Changing the Global Pandemic Situation

Jiya Chatterjee
Staff Writer

The COVID-19 pandemic has been raging on for over a year now, and now that scientists have gained a better understanding of the impacts of the virus, it is safe to say that the world has made some progress regarding containment of the virus. On December 11, 2020, the Food and Drug Administration (FDA) issued approval for emergency use of the Pfizer-BioNTech vaccine in the United States, which is now available for people 16 years of age or older. In parallel, other institutions producing vaccines such as the Moderna vaccine, Oxford-Astra-Zeneca vaccine, and Johnson & Johnson vaccine began distributing globally in the following weeks. All of the vaccines have impressive efficacies: Pfizer's efficacy is 95%, Moderna is 94.1%, Astra-Zeneca is 67%, and Johnson and Johnson's efficacy is 67%. Efficacy, as per Center for Disease Control and Prevention (CDC), measures the proportionate reduction in cases amongst vaccinated people based on results from a clinical trial. By May 3rd, 2021, 3.6% of the global population had been fully vaccinated. However, what have been the ramifications of this mass vaccination in controlling the pandemic–has transmission of the virus decreased after vaccines released globally, and are less people getting sick?

Of the top four countries who were severely impacted by the pandemic, China, the United States, India, and the United Kingdom, 40% of the US's population, 36.7% of the UK's population, and 3.11% of India's population have been fully vaccinated as of May 29th, 2021. China has not officially published any globally available data yet on their vaccination rates. The country that has reached the highest vaccination rate as of yet is Israel, with 59.3% of the Israeli population being fully vaccinated.

> "Allowing a silent viral spread to occur will likely result in new variations of the COVID-19 forming."

These numbers are a positive sign for the most part. The CDC recently published data that shows that people who are vaccinated have a lesser chance of being infected. However, this does not mean that transmission rates have reached zero, or that they will even reach zero at all by the end of this year or in the future. Transmission of the virus can occur between two vaccinated people– although, according to the CDC, vaccinated people who are infected have a lower viral load s than unvaccinated people. The two vaccinated people probably will not experience any symptoms, but they may continue contributing to a viral spread, especially if there are a large number of unvaccinated people globally. According to experts in infectious diseases from Georgetown University, Dr. Angela L. Rasmussen and Dr. Saskia V. Popescu, allowing a silent viral spread - a spread that occurs asymptomatically, to continue will likely result in new variations of the COVID-19 virus. "Until there is widespread implementation of robust surveillance and epidemiological measures that allow us to put out these smokeless fires, the COVID-19 pandemic cannot be fully extinguished," the pair wrote in a recent journal article. The most dangerous aspect of a silent viral spread is that despite not affecting vaccinated people with severe symptoms, it will cause unvaccinated people to contract the virus and increase the chance of hospitalizations and deaths. There are still a large number of people who are unvaccinated globally, and data has shown that the spread of the virus amongst that population is significantly higher. As analysed and published by the Washington Post on the week of May 26th 2021, in the US, where 40% of people are already vaccinated as of May 29th, 2021, the rate of infection is 73% higher amongst unvaccinated people than the number published for the full population of the US.

While the scientific community understands the above issue, vaccines are building confidence amongst people to take off masks and get back to a normal lifestyle; thus, new cases are still being reported daily especially amongst unvaccinated people, because it seems to many that the pandemic is essentially over. "It is unfortunate, but not surprising, to me that you are seeing increases in the number of cases per day in areas—cities, states or regions—even though vaccines are being distributed at a pretty good clip of 2 to 3 million per day," Dr. Anthony Fauci, an expert in infectious-diseases, noted in a recent conference on the COVID situation in the US. States that had avoided the worst of the pandemic. Vermont and Michigan are two examples, and they have been struggling to curb a possible disaster, with the latter state reporting an 80% spike in cases as of April 29th.

There are a number of explanations as to why cases have been steadily increasing in unvaccinated populations, especially in countries such as India. In India, 412,262 new coronavirus cases were reported in a single day in May 2021. On that same day, 3,980 deaths were tallied by the country, adding to the rapidly growing number of tragic deaths the country has experienced these past few weeks. Between April 6th and May 7th the country has recorded 8.3 million new cases. There are insufficient numbers of oxygen tanks, ICU beds, medicines, and trained medical staff, as well as an acute shortage of vaccines–India is unable to cope with the influx of COVID patients each day.

One of the reasons behind the latest surges of infections is that many governments, including India, have been lifting COVID guidelines that were implemented at the beginning of the pandemic, with the false hope that the global pandemic was under control. On April 10th, massive crowds gathered in the state of Uttarakhand in India for the celebration of Kumbh Mela, a Hindu religious holiday. The government made no move to cancel the event nor impose any restrictions. Consequently, 1,600 cases were recorded between April 10th and the 14th in the city where the festival took place, and there was a rapid spread to other states through the festival goers who returned home. Despite having low vaccine supply and vaccine administration rates, the Indian government's and the community's confidence in the idea of a natural herd immunity and Indian vaccines being available have been the driving factors behind their complacent behaviour towards the evolving COVID crisis in India.

In the US, in 24 states there are no regulations regarding masks–that is, residents, whether vaccinated or not, are not mandated to wear them, despite recommendations for unvaccinated people to do so by the Center of Disease Control (CDC) and the World Health Organization (WHO). In Florida, where cases have been rising significantly, the governor signed an executive order at the beginning of May that suspended all local COVID-19 restrictions until July 1st, after which all of the federal regulations will also be invalidated in the state. The governor has been criticized by the media and fellow politicians, mainly because all of his orders were not based on science but more so based on the false notion that the pandemic was over. Not surprisingly, Florida has been recording an average of 2,000 cases daily in the week of May 26th.

> On March 13th, 1.357 million people came through US airports–the highest number noted in a single day since the start of the pandemic in March 2020.

A further cause of the increase in new cases can be attributed to the rise of travel to and from places. On March 13th, 1.357 million people came through US airports–the highest number noted in a single day since the start of the pandemic in March 2020. Those who are traveling do not yet have to show their vaccine cards to board a flight, and even if they are vaccinated, as established earlier, being vaccinated does not necessarily guarantee that a person is not carrying the virus or one of its variants from another part of the country or the world. The concern garnered by the COVID-19 variant B.1.351, which is prevalent in South Africa, as well as B.1.617, the variant that is prominent in India, has led to more travel restrictions and recommendations, whether one is vaccinated or not.

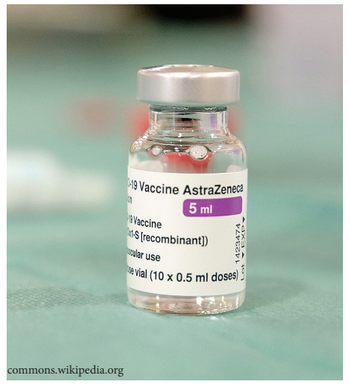
Mutations of viruses are very common, especially the coronavirus, since COVID's genetic material is made up of RNA. RNA is one of the factors that leads to multiple mutations occurring. Essentially, when a virus enters a host, such as a human body, it uses its genetic material to latch on to the healthy cells. It then hijacks the healthy cell, inserting its own genetic material into the genes of the healthy cell so that the body is forced to copy the DNA or RNA of the virus. Once the virus begins to be mass produced by the body, this is when a person is considered infected by a virus and thus becomes sick. Sometimes though, during this process of copying the genetic material of the virus, an error may take place and this is how a mutation occurs. Such an error modifies the gene and can sometimes make a virus stronger or weaker. In the case of COVID-19, variants B.1.351 and B.1.617 are stronger, more infectious versions of the coronavirus than the variant that affected the population in Wuhan, China originally.

It is clear that despite having multiple vaccines available, the risk of COVID-19 related health impacts, including short term symptoms, long term health degeneration, and death, continues to remain high. Infection rates, although not as high in certain parts of the world as they were at the start of the pandemic, are still increasing at concerning rates in other parts of the world which were not affected initially. The spread of the new variants will not decline unless governments and citizens continue to be vigilant and follow scientific guidelines and health protocols. More importantly, governments must ensure that there is equitable distribution of vaccines around the world. There are currently countries, such as Chad, that have 0% vaccines administered, according to TIME, mainly because the vaccine supply has not been directed towards developing nations. This is not only a question about equitable distribution; it is also about preventing continuous mutations through repeated surges in different parts of the world. Moreover, a positive attitude towards a new normal is important, where finding new flexible ways and solutions to live a day to day life safely by keeping scientific information and guidelines in mind should be the norm rather than believing that one can go back to the old normal. We have a moral obligation to our loved ones, friends, community members, and fellow human beings to be aware of how our behaviour plays an important role in containing this pandemic. If we continue to wear masks, socially distance, get vaccinated, and most importantly educate ourselves about the evolving science that supports healthy lifestyle, we can work to bring this distressing, saddening chapter in the history of the world to a close.

mRNA Vaccine Technology and Comparison to Typical Vaccine

Athena Rem
Staff Writer

The COVID-19 vaccines are predominantly mRNA vaccines. mRNA is a complementary strand to DNA and instructs the ribosomes on which proteins to make based on the instructions it carries from the DNA. This kind of vaccine technology dates to approximately thirty years ago, when scientists wondered if injecting a person with the structure of the mRNA that makes a virus' protein coat would act similarly to a typical vaccine. The first mRNA vaccines to be approved for use by the CDC are the most common COVID-19 vaccines, Pfizer and Moderna. Scientists had to experiment and discover exactly how the mRNA vaccines must work in comparison to typical vaccines, such as the flu or measles vaccines, to be able to create a functioning one to prevent COVID-19. These mRNA vaccines exhibit various differences to typical vaccines.



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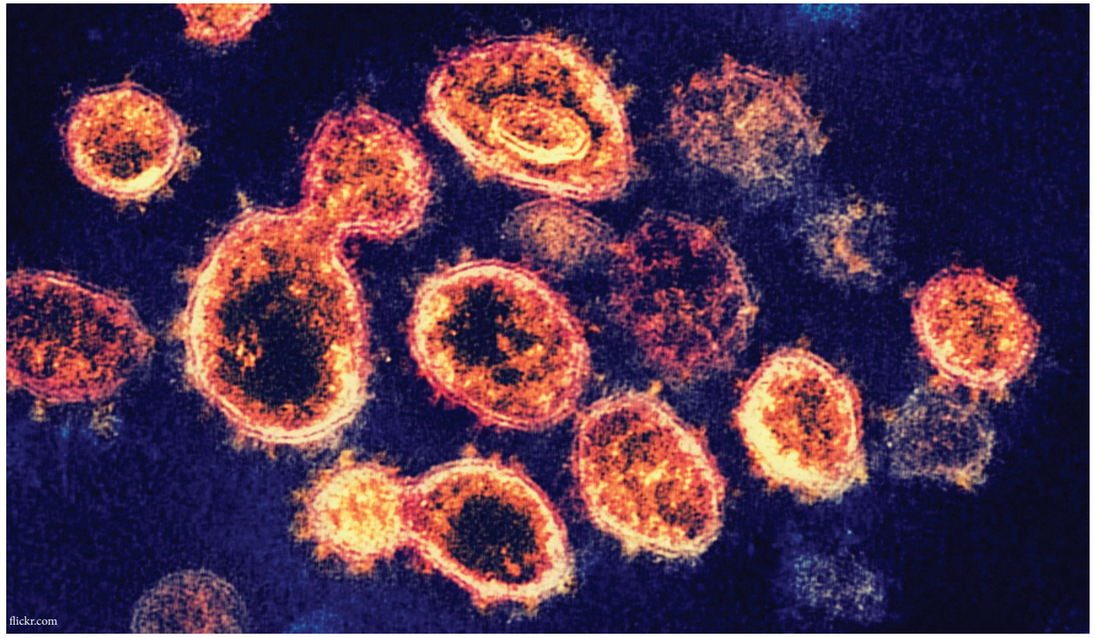
Though mRNA vaccines are commonly associated with COVID-19, they were experimented with beforehand. For example, mRNA vaccines were considered for viruses such as the flu, Zika, and rabies. Yet, these never got approved or distributed because the RNA in these initial vaccines was immediately destroyed by the body before being able to act on the immune system. In recent years, scientists had to solve this problem by encasing the RNA in a lipid. As such, scientists had to adapt to many new issues when trying to manufacture an mRNA vaccine. Dr. Anthony Komaroff of the Harvard Health Letter outlined four key obstacles that scientists had to deal with: avoiding large and potentially dangerous immune system reactions when using mRNA, making the immune system actually receive the mRNA as it passes through the bloodstream,finding a way to make sure the cells within the immune system make enough of the coded protein, and preventing chemicals in the blood from destroying the mRNA.

From this research alone, scientists learned another difference between typical vaccines and mRNA vaccines: mRNA vaccines are useful for building immunity to any given virus by more effectively instructing the immune system to make both antibodies and "killer" T-cells. To further compare these two types of vaccines, it is imperative to understand how each one works.

On a molecular level, mRNA is essentially the instruction that directs the synthesis of a protein during translation. mRNA directs the cells in the immune system to synthesize the protein and discard the mRNA. The immune cell then puts the protein on its surface, allowing the immune system to recognize that this is a non-self and unwanted protein and having the body start making antibodies that will be able to fight the real virus.

There are two types of non mRNA-vaccines: inactivated and attenuated. Inactivated is simply the protein coat for the target virus and live/attenuated is the actual virus, the latter being the same in a weakened form. The flu vaccine is inactivated, and works by recognizing the protein coat from the flu virus and attacking anything that the body recognizes as being the same. An example of a live vaccine is the common measles vaccine. Similarly, the immune system creates antibodies to fight the virus after receiving a form of it. The difference, however, is that in this case the body receives a weakened form of the virus, rather than a dead one.

These two types of vaccines -- mRNA and traditional -- have similarities and differences. For instance, both vaccine types teach the immune system how to recognize the virus and create antibodies for it. There are, however, many more differentiating factors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between these vaccine types. First, production of mRNA vaccines is much more efficient, having been estimated to take roughly a week to produce experimental mRNA. This process is so short because the mRNA can be made from a DNA template within a lab and can adapt to different pathogens, cutting down the specificity needed in a traditional vaccine. This is much faster in comparison to the months it can take to produce a typical vaccine, especially since these vaccines tend to be extremely different, unlike the mRNA vaccines.

Moreover, the mRNA vaccines are more effective; recent technology allows the mRNA to be packaged in lipids. The mRNA is more effective as it can be delivered to the immune system in larger numbers and more easily. Once there, the mRNA will produce more spike proteins (the same proteins that compose COVID-19), triggering a stronger reaction from the immune system than a typical vaccine, in turn increasing antibody and T-Cell production.

Before the vaccines are used, they must be produced. Typical vaccines are less safe in the production process than mRNA vaccines. In the case of attenuated typical vaccines, batches of the virus must be cultivated before making the actual vaccine, providing an opportunity for any number of biohazards and risks of infection. Conversely, the mRNA vaccine is much safer. While small quantities of the virus are needed for gene sequencing and vaccine testing, mRNA is non-infectious and is much safer for researchers and scientists to handle.

> In England, deaths among those aged 20-64 dropped 47% after the vaccine started being distributed.

These qualities of mRNA vaccines make them so useful during this COVID-19 pandemic, and the impact they had this year was astounding. In England, deaths among those aged 20-64 dropped 47% after the vaccine started being distributed. The trend of vaccination decreasing deaths continues among other age groups in England, and in studies in Scotland demonstrate the same result

mRNA vaccines have been in development for a long time, and are finally emerging as a safer, easier, efficient, and effective alternative to typical vaccines. While mRNA vaccines are not perfect yet, their effect on the COVID-19 pandemic has been instrumental in reducing death rates and infections. For these reasons, mRNA vaccines have the potential to be the future of vaccinations.

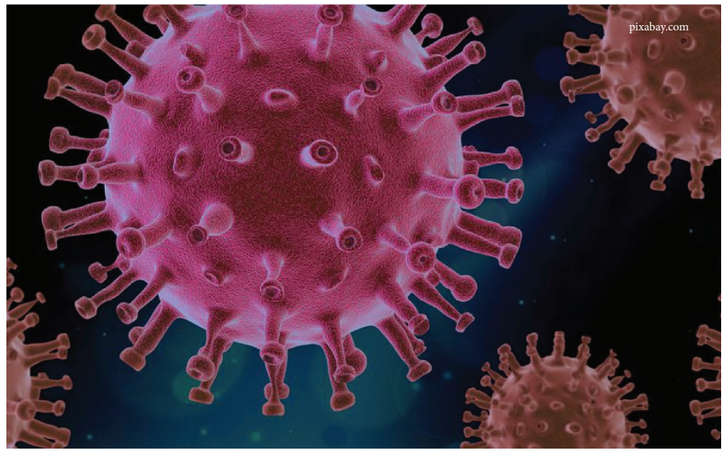
Neanderthal Genes May Increase Risk For Severe Covid-19

Zahra Motwani
Staff Writer

In two recent studies, one from the New England Journal of Medicine and the other from the COVID-19 Host Genetics Initiative, a stretch of DNA on chromosome 3 containing multiple genes was found to be associated with increased risk of severe COVID-19. However, the reason why this specific haplotype– a block or cluster of genetic variants that is usually inherited together— is responsible for such pronounced risk is unclear.

Researchers Shintara Hojyo, Mona Uchida, Kumiko Tanaka, Rie Hasebe, Yuki Tanaka, Masaaki Murakami, and Toshio Hirano discovered that when COVID-19 enters the body, without the stretch of DNA, the body's immune response is typically aggressive. However, people with this stretch of DNA have an overly aggressive immune response to COVID-19 that can be fatal. Without this stretch of DNA, when SARS-CoV-2 enters a cell, the cell triggers the production of IL-6, an interleukin, which is a group of small proteins that invoke responses in other cells (cytokines). Additionally, IL-6 is not just an interleukin but also a pro-inflammatory cytokine, which means it is an inflammatory mediator and can therefore promote muscle atrophy. Furthermore, IL-6 is also an anti-inflammatory myokine. One myokine comprises hundreds of cytokines, and an anti-inflammatory myokine reduces swelling. This IL-6 production causes an inflammatory response in immune and non-immune cells.

In some situations, when SARS-CoV enters the cell, it will lead to excess Angiotensin-converting enzyme II (ACE2). ACE2 is an enzyme on a cell's membrane. ACE2 is on cells in the lungs, arteries, heart, kidneys, and intestines. When extra ACE2 is produced, it causes Angiotensin II to be produced more. Angiotensin II is a peptide hormone that increases blood pressure, which causes IL-6 to continue to be produced. The Angiotensin II and AT1R signaling also trigger a series of proteases, enzymes that can break down proteins, triggering binding, signaling, and growth proteins that trigger pathways creating an inflammatory response. The excess IL-6 produced makes an IL-6 positive feedback loop for inflammation in non-immune cells. This loop causes a cytokine storm— an immune reaction where too many cytokines are released into the blood too quickly— that can cause acute respiratory distress syndrome (ARDS), severe pneumonia, multi-organ failure, and possibly coagulation. This response to SARS-CoV-2 is dangerously more aggressive when the patient has this inherited DNA. Unfortunately, it has not yet been reported how the body responds to SARS-CoV-2 with this DNA. Considering how severe the potential diseases already are from the cytokine storm, with this DNA, since the body responds even more aggressively, there is a higher chance that the immune system will fail, increasing the possibility of death.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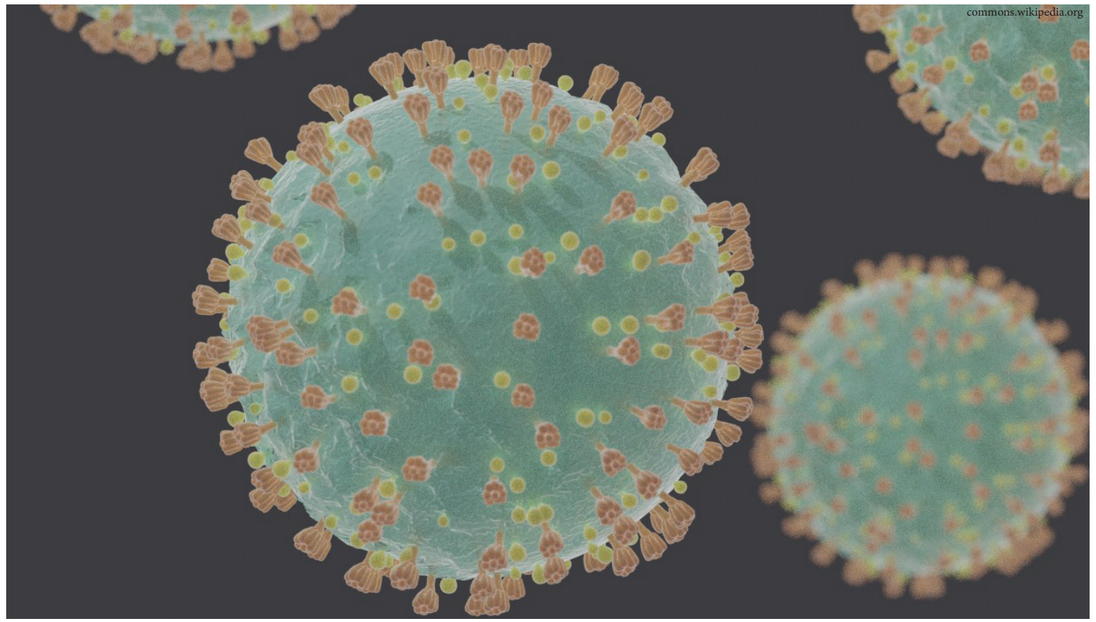
The study concluded that the risky haplotype consisted of inherited neandertal DNA, shedding new light on what makes this gene cluster so unique.

One unique aspect of the "risky haplotype" that researchers Hugo Zeberg and Svante Pääbo studied was that it was very long— 50,000 bases— and that all of the genes on it were in high linkage disequilibrium. Linkage disequilibrium means that these genes are strongly associated with each other and are very likely to be inherited together, more so than most genes in the general population. Zeberg and Pääbo found that such long haplotypes tended to be inherited from interbreeding between ancient humans and ancient human-like organisms, such as Denisovans and Neanderthals. During the study, Zeberg and Pääbo had to figure out which of the two different groups of ancient human-like organisms — Neanderthal or Denisovan — were the source of this specific haplotype. The majority of the genetic variants in the haplotype were traced to a Neanderthal from Croatia, 50,000 years ago. Two other Neanderthals, the Altai, and Chagyrskaya, had other genetic variants on the haplotype as well, but none of the genetic variants were traced back to Denisovans.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The study concluded that the risky haplotype consisted of inherited neandertal DNA, shedding new light on what makes this gene cluster so unique. Additionally, the haplotype was found to be most prevalent in people of South Asian heritage, specifically Bangladeshi people.

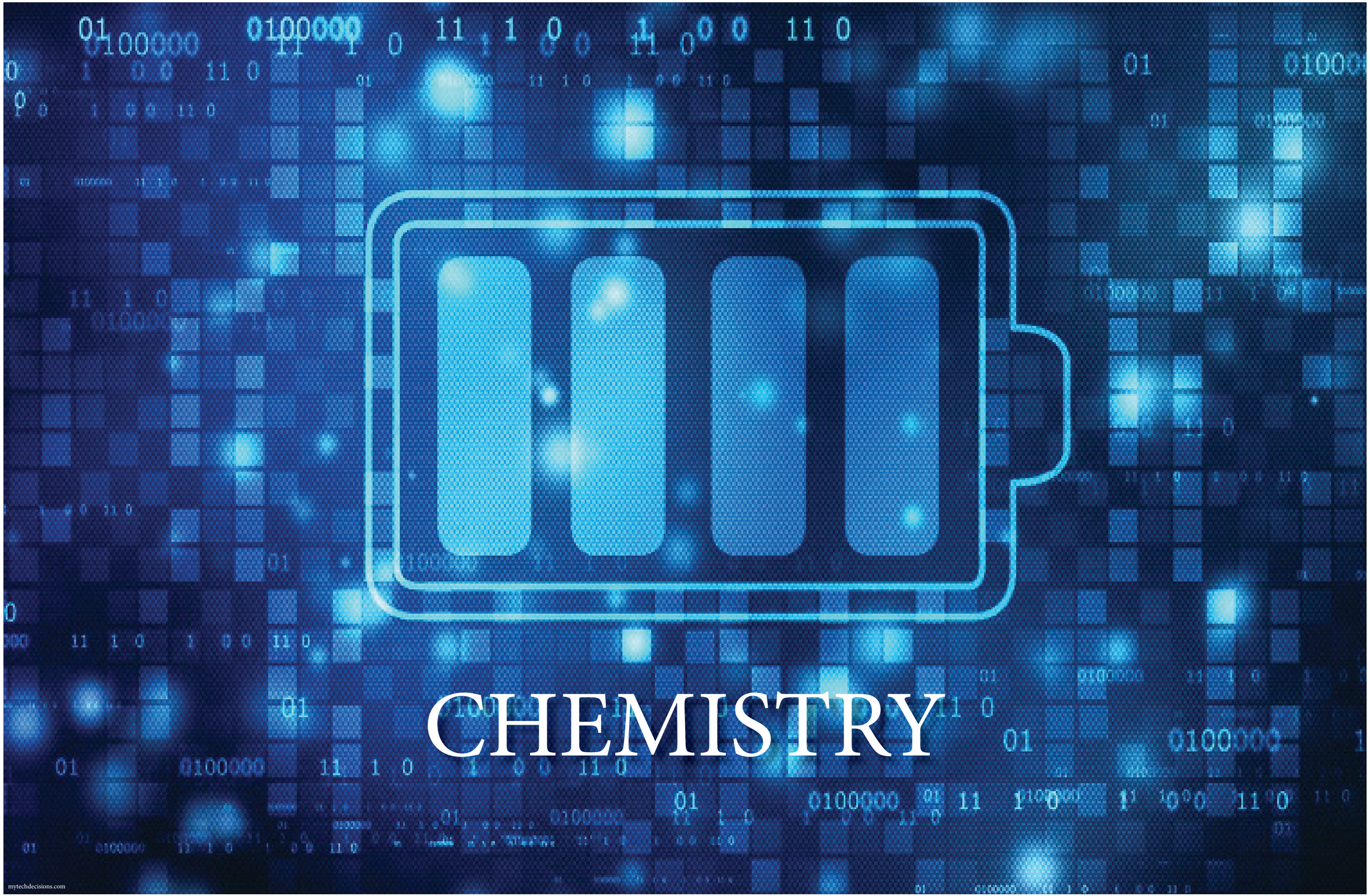
Zeberg and Pääbo found this haplotype associated with a risk of getting COVID-19 from a genome-wide study on 1,980 patients diagnosed with SARS-CoV-2 and respiratory failure throughout seven hospitals in Europe. With an equal amount of control patients and infected patients, they found that there were 8,582,968 single nucleotide polymorphisms, multiple forms of phenotypes in a population of species. They analyzed the data through a meta-analysis, which looks at data from several studies, and discovered that the nucleotides were associated with a gene cluster on chromosome 3, 3p21.31, which can increase a COVID-19 patient's susceptibility to respiratory failure.

It is important to note that the ability to have Neanderthal DNA is not a novel discovery, nor is it always associated with disease risk. People of all ethnicities from all over the world have been found to have percentages of Neanderthal DNA. For example, people of East Asian descent are typically found to have the highest proportion of Neanderthal DNA, but the specific risk-associated haplotype is not found in that ethnic group, so the risk of COVID-19 for them is not as pronounced as it is for people of South Asian descent.

The 1000 Genomes project investigated the prevalence of the risky haplotype throughout the world and found that it is present in 30% of people in Asia, 8% of people in Europe, and 4% of people in the US. Further, 50% of South Asians have at least one copy of the gene, and 16% of Europeans and 9% of multi-racial Americans have one copy. Most drastic was the prevalence in Bangladeshis: 63% of Bangladeshis have one copy, and 13% of Bangladeshis have two copies. The project also noted that in the UK, Bangladeshi people are two times more likely to die from COVID-19 than the general population. This indicates that having this gene could increase a patient's risk of dying from COVID-19, though it is not the sole reason why Bangladeshi people in the UK with this gene have died from the virus.

Although the haplotype is one part of the progression of COVID-19, it is not the only contributing factor for a patient's susceptibility to getting infected, the severity of the disease, or the progression of the disease. Socio-economic factors, the environment, and health conditions are large contributing factors.

Structural inequality in the UK is partly responsible for Bangladeshis' susceptibility to the virus, as Bangladeshi immigrants to the UK typically have low socioeconomic status, less quality healthcare, and work as essential workers — all of which increase their susceptibility to COVID-19 because of increased exposure. This gene can not be entirely responsible for the mortality of Bangladeshis, or anyone, because exposure, healthcare, and resources, as well as much more, are the larger contributing factors.


CHEMISTRY

NEW SILVER ZINC-OXIDE BATTERY REVOLUTIONIZES CAPACITY AND ENERGY DENSITY

SOPHIE DAUER
STAFF WRITER

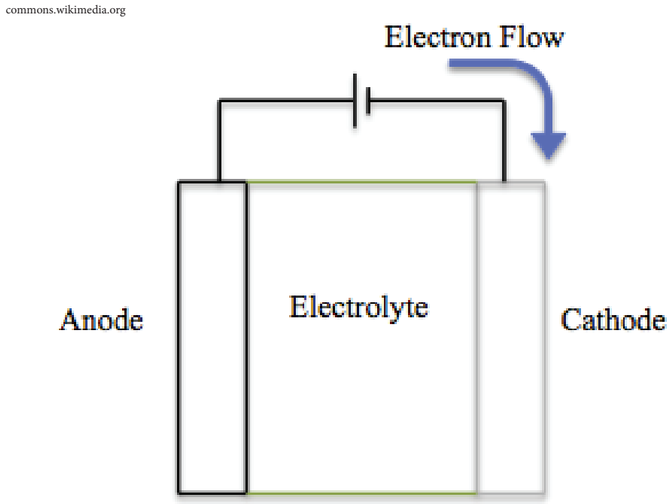
A team of researchers from the University of California San Diego and California-based micro battery developer Z power recently developed a new silver (I) oxide-zinc (Ag2O-Zn) battery that will have major impacts on the future of the development of high-performance flexible batteries. This battery, with its screen-printed manufacturing and silver-zinc chemistry which uses an unusually-high oxidation state of silver, exceeds others in its capacity and energy density. In fact, the new battery offers a higher capacity than any flexible battery currently on the market. Its flexibility, rechargeability, low impedance, and customizability make it ideal for use in flexible, stretchable electronics — from wearable gadgets to soft robotics. The battery grants engineers freedom in their design of electronics as it can be designed around electronics instead of the other way around.

Many commercialized flexible zinc (Zn)-based batteries already exist, but this battery is unique in its use of a higher oxidation state of silver that allows it to be highly rechargeable with a high capacity and low impedance. Zn anode chemistry is commonly used in flexible batteries due to its low material and production cost, its high theoretical capacity, and its rechargeability. The new silver oxide-zinc battery has all of the advantages that come with using Zn, while overcoming the shortcomings of current Zn-based batteries that use the lower oxidation state of silver (Ag2O): low rechargeability, limited capacity, and high internal resistance.

Batteries work by storing chemical energy and converting it to electrical energy through the flow of electrons from

"ONCE FURTHER TESTED AND TWEAKED, SOFT ROBOTS COULD BE USED TO DELIVER DRUGS, IMAGING AGENTS, AND GENES TO SPECIFIC BODY SITES."

a negative electrode, called an anode, to a positive electrode, called a cathode, and then out through an external circuit. At



the anode, the electrode reacts with the electrolyte, which balances the negative flow to produce electrons. At the cathode, a reaction allows the electrode to take in those electrons. Reactions that involve an exchange of electrons are called reduction-oxidation, or redox, reactions. During the reaction, the cathode is reduced as it gains electrons, and the anode is oxidized as it loses electrons. Two conducting materials with different standard potentials, or a difference in their abilities to produce or pull electrons, can form an electrochemical cell — a device that generates electrical energy from chemical reactions and the device that underpins the battery. Rechargeable batteries can reverse the negative-to-positive electron flow so that the system can run again.

The new silver oxide-zinc battery utilizes a Zn anode and an AgO cathode. At the anode, Zn ions (Zn2+) react with hydroxide ions (OH-) to release electrons. This half-reaction is similar to that of typical zinc-based batteries; however, the reaction at the cathode differentiates it from the rest. Typically, the lower oxidation state of silver (Ag2O) is used, but the new battery uses a higher oxidation state (AgO) in its reaction: $2AgO(s) + H2O + 2e- \rightarrow Ag2O(s) + H2O(l)$. This reversible redox reaction enables the cathode to receive electrons, and the higher oxidation state enables a higher theoretical cathode capacity and a lower impedance. ZPower's AgO cathode material relies on a proprietary lead oxide coating to improve the electrochemical stability and conductivity of AgO, which is typically less stable and less conductive.

Many flexible batteries are expensive to produce as they typically must be processed in a vacuum with entirely sterile conditions. Scientists create this new battery, however, through a low-cost screen-printing process in

"THE NEW SILVER OXIDE-ZINC BATTERY HAS ALL OF THE ADVANTAGES THAT COME WITH USING ZN, WHILE OVERCOMING THE SHORTCOMINGS OF CURRENT ZN-BASED BATTERIES THAT USE THE LOWER OXIDATION STATE OF SILVER (AG2O): LOW RECHARGEABILITY, LIMITED CAPACITY, AND HIGH INTERNAL RESISTANCE."

normal laboratory conditions. The creation process of the cells utilizes a layer-by-layer printing of inks to form the current collectors, zinc anode, silver cathode, and their corresponding separators. The battery is assembled in a stacked configuration, with a low impedance electrolyte placed between the two printed electrodes. The battery is heat-sealed and vacuum-sealed to ensure the correct cell pressure and preservation of the electrolyte. This creation and assembly process can be used for different cell sizes with adjustable areal capacity, allowing a customizable battery that can be tailored for specific needs.

With a higher capacity than any other flexible battery currently available, this device can power flexible and stretchable electronics for wearable devices as well as soft robotics. Soft robots, flexible machines engineered out of soft materials, have important potential uses in medicine and manufacturing. Small robots can navigate and perform operations in hard-to-reach areas of the body, meaning that these robots could potentially eliminate the need for invasive procedures in many instances. The robots do not harm tissues due to their size and soft nature. Their shape can be programmed to adapt to their surroundings. The powerful and flexible zinc silver-oxide battery is ideal for this. There is an overall need for more research before soft robots can be applicable for medical use. However, once further tested and tweaked, soft robots could be used to deliver drugs, imaging agents, and genes to specific body sites. Additionally, through their low-impact nature, soft robots could contribute to a greener earth with their potential use in a field with a large carbon footprint and their potential use in the maintenance and repair of solar panels, wind turbines, and other similar devices. The new silver zinc-oxide battery, with its flexibility, rechargeability, high areal capacity, and low impedance, is incredibly important for the future of flexible electronics, and could potentially translate to advances and benefits in areas such as medicine and the environment.

New Battery Powered by Humans is Invented

William Bramwell

Staff Writer

A major breakthrough in the field of renewable energy may bring the world closer to a carbon-neutral future with less environmental carnage. A team of scientists and engineer s from the University of Colorado Boulder have developed a product that can harvest thermal energy naturally released by humans and convert it into electricity, transforming the body into a "biological battery." It is a novel variation on a machine called a thermoelectric generator (TEG) that uses heat to conduct electricity. If one can gets past the eerie similarities between this new device and the dystopian world portrayed by the popular 1999 science fiction film The Matrix (in which alien life forms harvest energy from enslaved humans), it is evident that this device will be a force for good and positive change in the world. It could revolutionize the fundamental way energy is extracted and employed.

Although the technology to convert human energy into stored electricity has existed for years, this new device is stretchy and malleable, making it suitable to be worn comfortably as a ring, wristband, or even a necklace. It looks like a circuit board with protruding spikes. Another feature that sets this new TEG apart from previous models, which have been brittle and inconvenient, is its use of interchangeable parts. The lead scientist and senior author of the published paper detailing the invention, Jianliang Xiao, has compared this invention to Lego toys since the device has a basic repeated unit or module that can be tacked onto itself.

What separates this new device from previous TEGs is its adaptability to the human body. This flexibility stems from its Lego-like nature, in which its individual and interchangeable units allow the product to be easily repaired after damage. This self-healing process is made possible by materials that can easily reconnect using chemical reactions and electricity. The metal computer wires, which are liquid in form, regain electrical conductivity after being broken or torn by being moved throughout the day. The base is made from polyimine, a substance that contains three compounds: terephthalaldehyde, methyldipropylamine, and trisamine. These compounds quickly form strong covalent bonds, bringing the broken parts of the interface together within an hour. To further increase reaction rate, the

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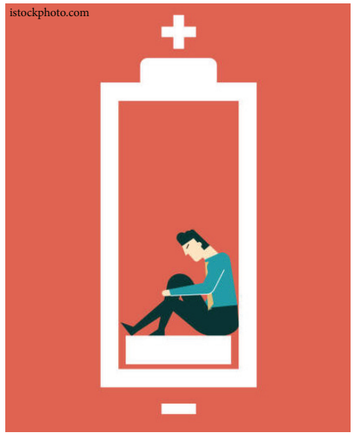
device also uses its stored energy to increase temperature, lowering the activation energy and acting essentially as a mechanical catalyst. This process of healing takes place within minutes.

The battery currently generates one volt of energy per square inch of human skin, which is less powerful than most existing batteries. However, this amount should still be enough to power smart phones and, currently, is already more powerful than some watch batteries. It is also water resistant because of its hydrophobic polyimine base, a beneficial addition when being used on human skin. Xiao expects the product to be brought to the market in five to ten years at low cost. By then, he hopes to have improved its efficiency. Xiao also experimented with "electronic skin," which behaves and acts like real skin. Just like the biological battery, the electronic skin uses a web of liquid metal wires wrapped around highly elastic polyimine.When broken apart, covalent chemical bonds immediately reform within the polyimine, as its activation energy, the amount of energy needed to jumpstart a reaction, is notoriously low. This readjustment process allows for potential future uses on human skin. Xiao envisions a future when watches, fitbits, and other products can be embedded as a thin film into skin, greatly cutting down on electronic waste. The epidermis of the artificial skin needs an external power source, but now it can be adapted into a TEG that powers itself from humans' natural internal body heat. Xiao's paper mentions how a future device could synthesize these two technologies into one, allowing for future cyborg-like technologies to become a reality.

All TEGs utilize what is referred to as the Seebeck Effect, or the Thermoelectric Effect, a type of diffusion phenomenon in which electrons flow from a warm area to a cold area. Discovered by German scientist Thomas Seebeck in 1822, the Seebeck Effect has a correlative equation used to calculate voltage: V = a(Th-Tc). Th and Tc are two different temperatures in physical space, and "a" is a constant called the Seebeck coefficient. Therefore, the voltage generated is "a" multiplied by the difference in temperature between a hot and cold junction of metals. In essence, the Seebeck Effect exploits temperature differentials to form voltage and electrical flow through space. Though at the small scale the Seebeck Effect only produces a few millivolts, Seebeck Effect devices can produce thousands of volts if placed together in large arrays. The new wearable battery takes advantage of this reality by placing many of the same individual units of a TEG over one another, producing more energy than one single large TEG would. The biological battery forces electrons to move away from warm human skin and toward colder air, creating a direct electric current. As such, this technology creates a completely self-sustainable source of energy powered by humans.

This new thermodynamic technology may pave the way for renewable and environmentally safe energy sources. The thermodynamic energy harvesting technique could be applied to other natural heat sources, such as animals and even thermal vents, generating vast amounts of eco-friendly, carbon neutral energy.

Moreover, the biological battery is even completely recyclable. Once finished, one can put the battery in a solution that dissolves the polyimine base and separates it from the electronic components. All of the remnants of the TEG can be reused and constructed back into another TEG. One can return the hardware to the lab and recycle the dissolved polyimine because polyimine can be separated into its component to then form



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covalent bonds and assemble into polyimine again.

This new thermodynamic technology may pave the way for renewable and environmentally safe energy sources. The thermodynamic energy harvesting technique could be applied to other natural heat sources, such as animals and even thermal vents, generating vast amounts of eco-friendly, carbon neutral energy. Currently, thermoelectric generators are used in extreme environments, generating heat in Antarctica, on spacecrafts, and even on Mars rovers. They can be used to extract vast amounts of energy from the heat released by nuclear decay, and the radioactive element plutonium has been proven to work well with thermoelectric technology. Xiao says that he and his team are "trying to make [their] devices as cheap and reliable as possible, while also having as close to zero impact on the environment as possible." Giving countries an opportunity to develop and industrialize in a less environmentally harmful way will be critical to limiting future carbon footprints. Advances in TEG technology may make it possible to generate energy from natural temperature differentials around the globe, decreasing current reliance on traditional fossil fuels, which are incredibly harmful to the environment and climate. In the future, TEGs may be a part of everyday life, with potential applications in clothing and fashion designs. The adaptability and self-restoration process of this new device differentiates it from so many others, opening the door to a future powered by thermodynamic electricity.

An Anode-Free Zinc Battery that Could Someday Store Renewable Energy

Benjamin Wu
Staff Writer

In recent years, as climate change has been an ever more imminent threat, there has been research into reducing carbon emissions in all facets of life. One thing that many are dependent on is electricity. Specifically, renewable energy is extremely important and helps to supplement electricity needs to reduce fossil fuel usage. Burning fossil fuels in the United States accounts for 92% of all carbon dioxide emissions, so finding a renewable energy source is paramount to drastically mitigating this number.Oftentimes, renewable energy is associated with technologies such as solar power, wind power, or geothermal power. These are all considered renewable energy generation methods. What's also important to consider however, is storage methods for renewable energy.

Traditionally, renewable energy has been stored using large lithium ion batteries. However, there are many drawbacks to lithium ion batteries. These batteries are prone to overheating, and potentially could be dangerous as they are relatively flammable, toxic and their performance is restricted to a low amount of usages. Furthermore, Lithium and Cobalt, important resources used in lithium ion batteries, have recently become a scarce and costly resource. As such, the continued use of lithium batteries is neither safe nor sustainable, and it is paramount that new batteries that can store renewable energy be developed.

One battery that has a lot of potential is an anode-free zinc battery. The phrase anode-free means that the battery does not include an anode, a part that is used in a traditional battery. By being anode-free, the battery does not waste any extra zinc in the fabrication process, making it very efficient. These batteries also address some of the flaws of the lithium ion batteries. Zinc is a much more common and cheaper material than Lithium, and the battery has a large theoretical energy capacity. The specific battery designed by Zhu and others had high stability, efficiency, and energy density, meaning that more energy could be stored into a smaller battery.


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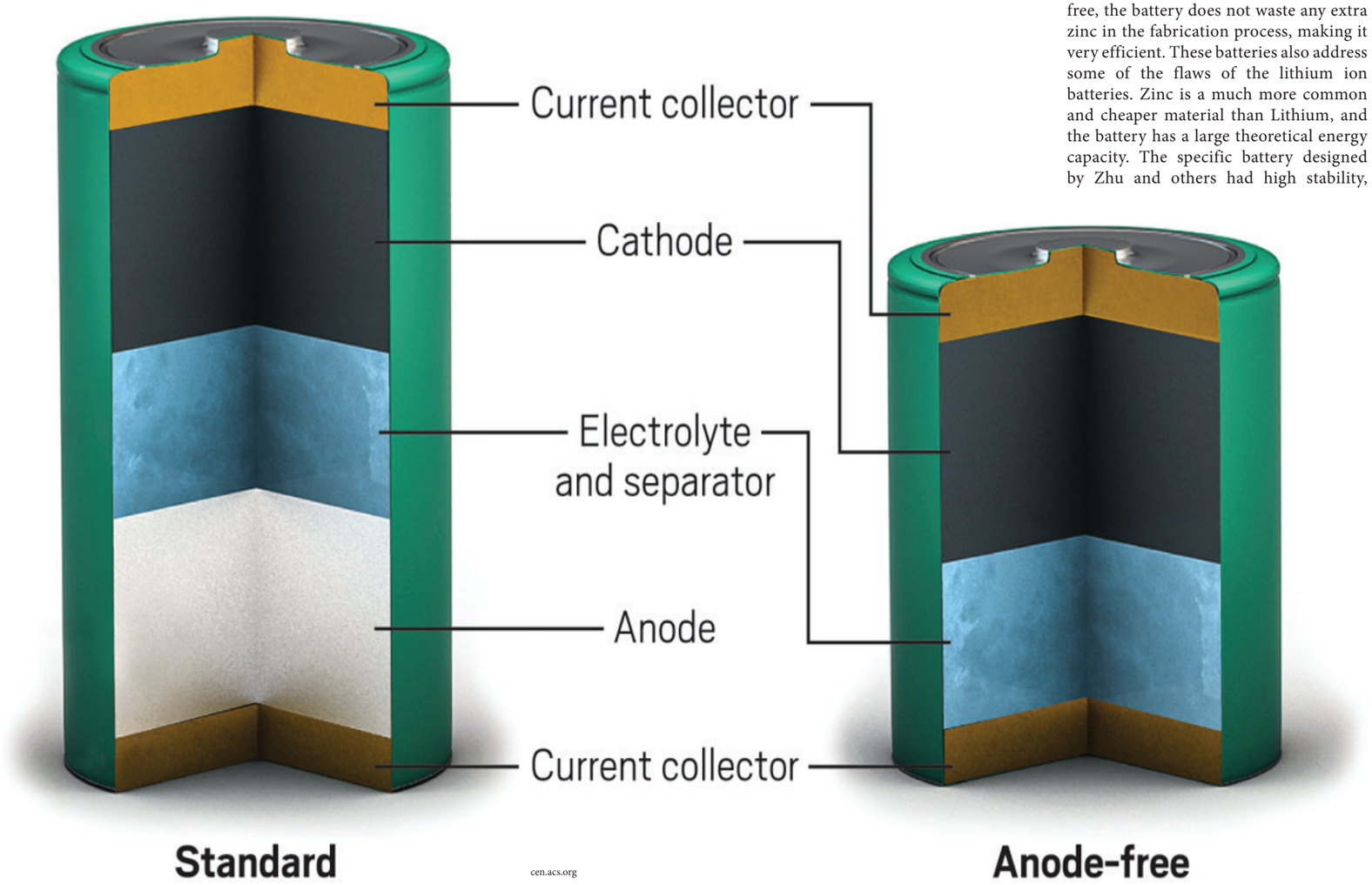
What allows for this battery to be so innovative is the method by which energy is released. There is a large focus on the cathode of the battery, or the negatively charged end. This cathode is interlaced with zinc ions, a zinc solution, and a copper current collector. The zinc ions move to and from the copper to store and release energy respectively. When charging the battery, the zinc ions attach themselves to the copper. When the battery is used, the zinc ions are stripped off of the copper, generating energy.

As impressive as this technology may seem however, there is still a long way to go. The authors of the paper admit that this battery may someday have the potential to store renewable energy, however the battery has not yet proven this capability.

Overall, no matter whether these batteries are able to store renewable energy or not, they are certainly a monumental technological advancement for sustainable and more efficient batteries, that regardless, will likely outclass the current lithium ones. There is even research being done using Aluminium, another very common material, to make batteries, just like Zinc was used in this case. It should be of the utmost importance for the scientific community to continue researching these batteries and look into new fields where sustainable or renewable methods have not yet been developed.



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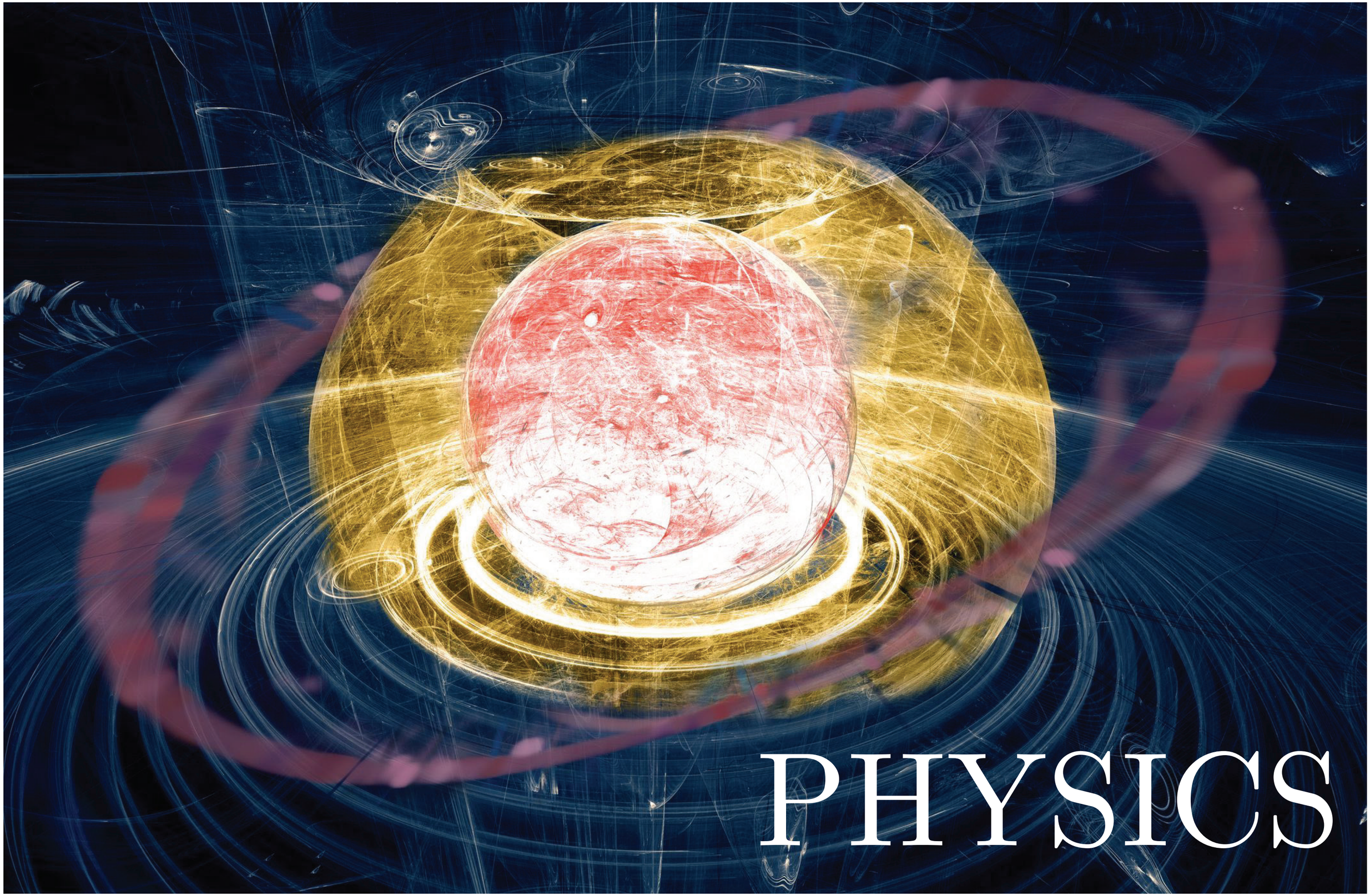
"By being anode-free, the battery does not waste any extra zinc in the fabrication process, making it very efficient."



PHYSICS

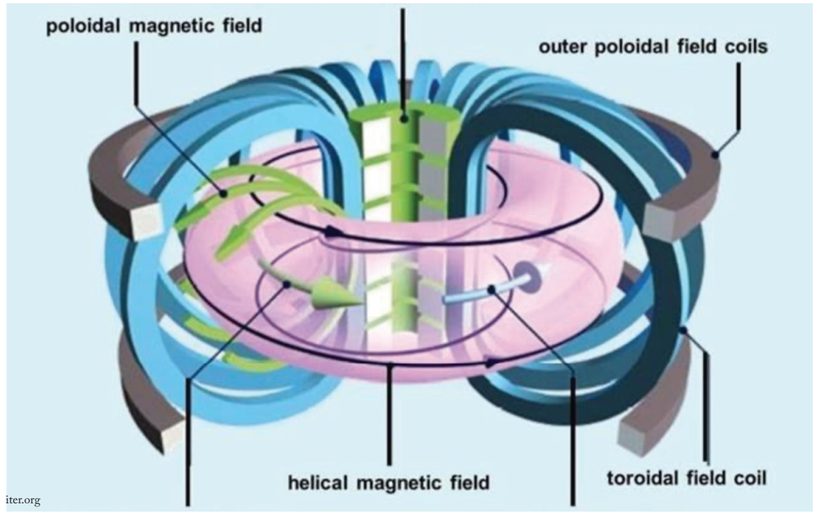
New ELM Breakthrough is an Important Step Toward the Future of Fusion Power

Elise Kang
Staff Writer

Under the leadership of Raffi Nazikian and Qiming Hu, physicists at the Princeton Plasma Physics Laboratory have modelled a method that allows for more stable energy containment. If the model's method turns out successful, then scientists will be one step closer to using fusion energy as a source of clean energy.

Fusion energy could be the solution to brown energy that scientists have been looking for. Fusion creates a byproduct of helium. Unlike other gases produced by energy production, helium is not a greenhouse gas, toxic, or combustible. Fusion — the process by which stars produce their energy — generates clean, safe, and abundant power, making it a perfect alternative to fossil fuels. However, this energy is highly unstable. Consequently, scientists must further research how to safely and reliably contain this energy in order for it to become a practical and widespread alternative to fossil fuels.

In fusion, light elements – hot charged matter composed of free electrons and atomic nuclei – in plasma merge to produce energy. There are two methods to achieve fusion – high pressure and high temperature. High pressure causes fusion by forcibly pushing protons together, generating energy. High temperatures cause fusion by increasing the rate at which protons travel within an enclosed space. If protons can travel faster, scientists hope that protons are more likely to come close enough to each other to be pulled together by electromagnetic forces, thus merging and creating fusion energy. Pressure is considered a more reliable way to create fusion because it allows for more control over the direction of proton movement. Pressure forces protons to merge towards each other instead of in random directions. High temperatures simply increase the rate of proton movement, but do not allow scientists to control where protons go with that speed. Additionally, extremely high temperatures can be quite damaging to metals used to construct machines that conduct fusion.



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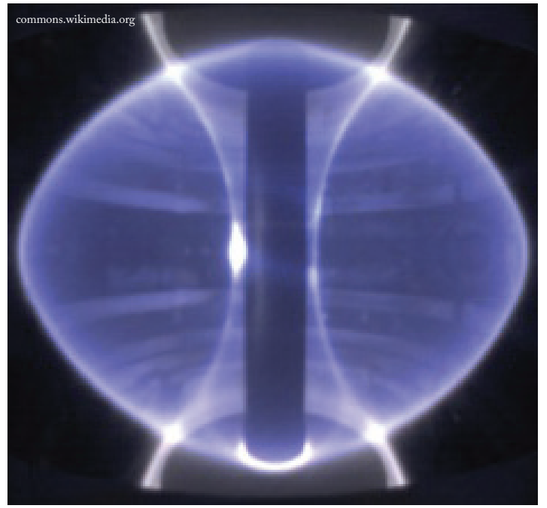
Scientists who hope to achieve a fully renewable and carbon-free source of energy look to develop tokamaks. Tokamaks are shaped in a torus, which is similar to a doughnut. In the middle of the torus is a cylindrical magnet called the central solenoid. The plasma stored by the tokamak spins around the central solenoid. The plasma and central solenoid are then enclosed by various other magnets and heating structures which work together to merge protons. In summary, tokamaks utilize magnets in various locations around the torus to create equal distributions of magnetic force around the plasma. Since protons are positively charged, applying either north- or south-poled magnets at the appropriate locations would either pull or push protons together to create energy. Tokamaks also use heat to stimulate fusion; however,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the amount of heat a tokamak can use to create fusion is limited because it can damage the parts of the tokamak.

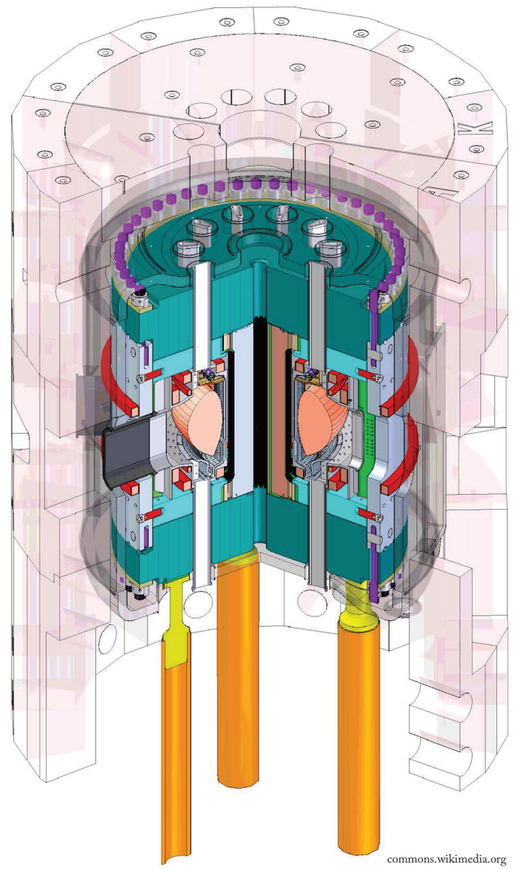
However, this technology is still developing. Tokamaks are subject to edge-localized modes (ELMs), which are intense bursts of heat and particles that can damage the reactor walls of the tokamak. ELMs originate from unequal pressure applied to the plasma. Balloons can serve as a good visual to understand ELMs. Suppose the tokamak is a balloon, and the plasma is the air inside the balloon. In order to create fusion energy using pressure, we want to exert equal force on all sides of the balloon to condense the air inside. However, imagine force is applied to all sides of the balloon except a small region on the right side of the balloon. What happens to the air inside the balloon? The air migrates to the unpressured region on the right and could eventually burst and create a hole in the balloon. This air migration is exactly what an ELM is, and is problematic because if a tokamak has this "leak," protons will escape the plasma. Accordingly, the pressure cannot force the protons to condense and will not create fusion energy.

In order to make tokamaks more consistent and reliable, scientists need to suppress ELMs. Current technology allows scientists to suppress ELMs by applying spiraling rippled magnetic fields called resonant magnetic perturbations (RMPs) to the surface of the plasma that fuels fusion reactions. However, this method only works under a very short range of electric currents in the tokamak. To make reliable and safe fusion plants in the future, tokamaks need to be able to cover a wider range of electric currents.

A recent scientific discovery made by physicists at Princeton Plasma Physics Laboratory may solve this problem. In their paper published in Physical Review Letters, Hu and Nazikian's team noted that RMPs could only suppress ELMs for specific values of the plasma's electric current. They then proposed that modifying the structure of RMPs should eliminate ELMs over a wider range of electric currents. RMPs work by pushing magnetic islands (see diagram) near the outskirts of the plasma back into the body, releasing the pressure that causes ELMs inside of them.

Hu and Nazikian's team produced a simulation that predicts when magnetic islands will form. Combining their simulation with their proposed method of suppressing ELMs by altering RMP structure could lead to the reliable suppression of ELMs in tokamaks. However, whether their strategy is viable remains to be seen, as these achievements are widely on paper and have not been field-tested yet.

Predicting the circumstances in which ELM suppression will work is one step in the right direction towards fusion energy as a safe and reliable green energy source. The implications of fusion energy are extensive. Fusion would give us a near-unlimited amount of renewable energy, since fusion power produces energy levels near that of a strong lightning bolt. Fusion power plants would produce much more energy per area than solar panels, which require a lot of space for panels to absorb the sun. If fusion power were to become a feasible alternative to brown energy, widespread fusion power plants could significantly lower our carbon footprint. Ultimately, while Hu and Nazikian's discovery will not single-handedly make fusion energy plants a reality, it plays a role in a much larger project – powerful, sustainable energy that humans can harness as an environmentally-safe alternative to fossil fuels.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World's Largest Fusion Reactor, ITER, is Set for a Test Run

Ayaan de Silva
Staff Writer

What is the future of energy? In recent years, it has become increasingly clear that fossil fuels, as an energy source, are not sustainable. The burning of these fossil fuels has led to a great increase in the amount of atmospheric CO2. This increase causes catastrophic warming and environmental destruction, making the need for a cleaner type of fuel increasingly apparent. One potential solution is nuclear fusion. However, despite its lack of greenhouse emissions and the vast amounts of energy it could produce, it does not often make its way into these conversations. Although, to the layman, fusion might seem more like a played-out trope of science fiction, steady research over the last few decades has begun to prove otherwise.

Nuclear fusion is the process that powers stars like the sun and many scientists want to replicate this process to power the earth. The cores of stars contain extreme temperatures and pressures that allow fusion to occur. Fusion occurs when two nuclei, usually hydrogen, merge into one heavier nucleus, typically helium. When this merging occurs, great amounts of energy are released due to a loss of mass in the resulting nucleus. Although greater than the mass of the individual hydrogen nuclei, the mass of the resulting helium nucleus is less than the mass of the two hydrogen nuclei together. The leftover mass from the hydrogen nuclei that doesn't become part of the helium nucleus is essentially converted into energy. This conversion can be explained by Einstein's equation E=MC2. This equation suggests that mass and energy can be converted into each other in certain instances. Due to the virtually unlimited supply of hydrogen on earth and the enormous amount of energy created by fusion, many scientists are looking to nuclear fusion as the future of energy. The International Thermonuclear Experimental Reactor (ITER) is one of the most ambitious projects attempting to carry out this vision.

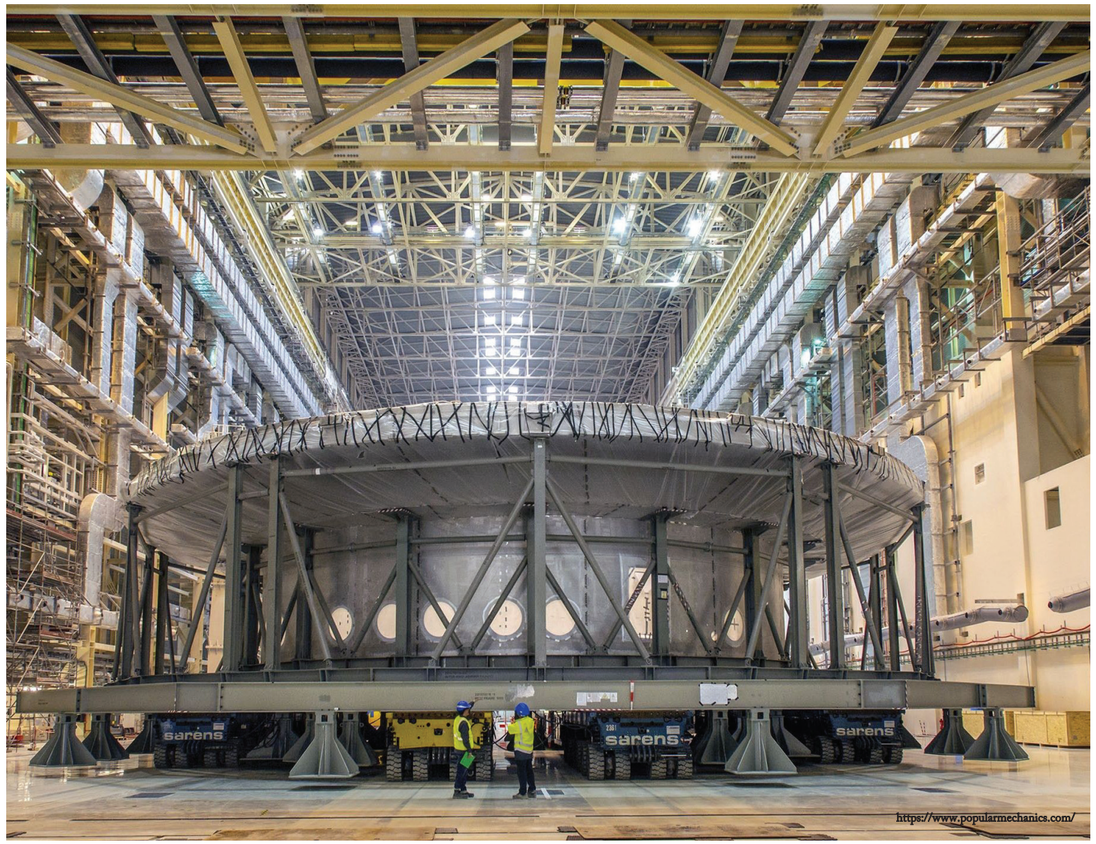
> "Due to the virtually unlimited supply of hydrogen on earth and the enormous amount of energy created by fusion, many scientists are looking to nulcear fusion as the future of energy."

ITER is a reactor being built in the south of France by over 30 countries. It aims to be the first fusion reactor to create net energy and run for long periods of time. Net energy is when the total energy produced by a system exceeds the amount of energy needed to be put in to sustain it. Creating a net energy fusion reactor has never been done before largely due to the great amounts of energy needed to replicate the core of the sun. Fusion in the sun's core takes place at about 15 million degrees celsius;in order for fusion to take place on earth, a reactor must reach around 150 million degrees celsius. As one might assume, reaching the gargantuan temperatures takes an enormous amount of energy but, in theory, once the ITER reaches this temperature, it should be able to sustain it without additional energy being added to the system.

The ITER is a tokamak: a donut-like structure in which fusion can occur. Inside the tokamak, there are two isotopes of hydrogen: tritium and deuterium. These two isotopes were chosen because they are the most efficient types of hydrogen. In essence, they achieve fusion at the lowest temperatures and are quite abundant. There is enough deuterium on earth to power humans for billions of years and tritium is easily created in the nuclear fusion process. These isotopes are then heated until they form a plasma and fusion occurs. When they fuse, tritium and deuterium produce a neutron, a helium nucleus, and energy. The neutron then comes into contact with the inner walls of the tokamak, which are lined with lithium and tritium is produced which can then be used for fusion.

Strong magnets line the tokamak in order to contain the hydrogen isotopes and their products. Each magnet weighs over 300 metric tons and is over 17 meters tall. These magnets are made of niobium-titanium and when this metal is cooled it causes the magnets to become superconducting. Superconducting magnets are able to create stronger magnetic fields than regular magnetic fields while being cheaper to operate and consuming less power. As a result of these magnets, the helium nuclei produced by fusion are unable to escape the plasma. Therefore, they end up colliding with tritium and deuterium, producing energy that sustains the high heat of the plasma. The plasma then heats the walls of the tokamak which in turn heats a body of water. This water then turns to steam and spins a turbine which generates electricity.

Although ITER isn't scheduled to start running until 2025, scientists have been using smaller reactors to conduct simulations. One such reactor is the Joint European Torus (JET) which, ever since December has been testing different fuel conditions and their impact on nuclear fusion. The main objective of the scientists at JET is to determine the effect of tritium on reactions. Although the combination of tritium and deuterium produces much more energy and many more neutrons than deuterium alone, these excesses typically interfere with a reactor's diagnostics system, making it harder for the scientists to gain data. The JET has been specially modified with these considerations. For instance, concrete walls have been built to protect the diagnostic instruments. The experiments at the JET represent an exciting new step toward a world built on clean renewable power.



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