COMPLEX REASONING: THE NEXT FRONTIER FOR AI

FORENSIC SCIENCE: REFORM TO A BROKEN JUSTICE SYSTEM

LINK V0.9: NEURALINK’S PLAN TO ENHANCE HUMAN INTELLIGENCE

THERE’S MORE TO GENDER THAN JUST XX AND XY
Letter from the Editors

Welcome back! It’s been nearly two years since SciTECH magazine was last published, and since that time, it’s fair to say that a lot has happened!

After a chaotic two years with the Covid-19 pandemic, we, the 7th Editorial Board, are thrilled to be revitalizing the magazine. We hope you can join us in this journey to explore the fascinating technological and scientific discoveries across the globe and within the Choate community.

As Choate’s premier STEM publication, we hope to continue sharing intriguing information about the latest research and progress in various STEM fields with the Choate community, serving as a platform to highlight research and STEM work by the Choate community, and providing a space for students passionate about STEM and journalism to connect.

In this issue, you’ll read about a variety of news in the fields of science, technology, engineering, culture, and hacks. For all the technophiles out there, you’ll be pleased to know that we have several articles ranging from the role of forensic science in fighting crime and reforming the justice system to the possibilities of complex reasoning as the next frontier for artificial intelligence.

Are you more interested in the cultural and societal aspects of science and technology? Not to worry! You’ll have the opportunity to read about how biological applications limit our understanding of gender identity and an overview of the 2021 Nobel Prize discoveries and winners. Rest assured that as long as you continue flipping through the pages of this magazine, you won’t be disappointed.

Nonetheless, as a new Editorial Board, we still have many areas where we can improve upon. We sincerely hope for you to contact an editor to provide feedback or any suggestions. We also encourage you to contribute article ideas, graphics, or pictures you would like to see or design and write yourself!

Happy reading!

Ryan Kim ’23  
Editor in Chief

Eva Li ’24  
Managing Editor
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FORENSIC SCIENCE: REFORM TO A BROKEN JUSTICE SYSTEM

By Isabella Wu ’24

To the wrongly accused, you are heard.

The criminal justice system, the crimes of a murderer, the pleas of the innocent — where does science have a place? Ever since the concept of utilizing fingerprints as a means of identification was first established during the 7th century, forensic science has become a critical element of the criminal justice system. Numerous scientific discoveries and technological advancements have made forensic science a key factor in determining guilt or innocence in major criminal cases.

The advent of DNA fingerprinting has revolutionized the science of criminal investigation: when this technique is performed, it is highly reliable in convicting or exonerating individuals. DNA profiling was first discovered by Alec Jeffreys in 1986 during a murder case. He matched blood and saliva samples to over 4,000 men until a match was found and proved that the police’s initial suspect was innocent. Since then, DNA profiling has grown faster and more reliable — scientists today can retrieve DNA profiles from skin cells with a mere touch of a surface, with user-friendly instruments that can run and analyze samples in under two hours. These improvements, combined with new data analysis approaches, allows investigators to identify multiple individuals in mixed samples.
DNA strands contain regions with short repeating sequences of bases at various spots — or loci — throughout the genome. These markers, called short tandem repeats (STRs), can be used to identify individuals. Scientists use a technique called capillary electrophoresis to measure the size of DNA fragments, in which small fragments travel through a gel-like material and register as a series of peaks in an electropherogram as they pass through a fluorescence detector. The development of polymerase chain reaction (PCR) by Kary Mullis in 1983 permitted scientists to retrieve intact DNA from much smaller samples. The process of PCR allows unlimited amplification of DNA traces as it can copy segments multiple times until they are easier to detect. The real game changer of DNA profiling came with the development of profiling databases. In earlier days, DNA was primarily used to include or exclude suspects. However, in order to utilize the analysis of crime scene samples, a specific suspect and their DNA were required. With the development of government databases of DNA profiles, such as the Combined DNA Index System (CODIS), investigators now have the ability to solve crime cases without needing to identify suspects first and can even match and connect suspects of seemingly unrelated cases to find serial offenders.

DNA technology has had a revolutionary impact in reversing wrongful convictions and reforming the criminal justice system. The year 1989 marked the first case of DNA exonerating in the U.S — Gary Dotson, convicted falsely of rape, was acquitted a decade later when PCR testing solved Dotson of the crime. To date, 375 people in the United States have been exonerated by DNA testing, including 21 who served time on death row. DNA testing has proved time and time again that wrongful convictions are not coincidences or one-time occurrences but rather systemic defects that must be improved upon as a part of criminal justice reform.

One of the most famous unsolved murder cases in US history is the Zodiac Killer. Fifty years ago, a postage stamp licked by the murderer was discovered — perhaps our only real hope of catching the notorious serial killer. The Zodiac Killer didn’t leave any traces of blood or semen at crime scenes; thus, the only traces of DNA police have found are the stamps he used to post his cryptic letters. San Francisco investigators were able to develop a partial profile by testing saliva traces from the stamps. While this incomplete profile couldn’t definitively convict anybody, it did rule out long-time suspect Arthur Leigh Allen and has helped narrow down the list of suspects. The murder of Cheri Jo Bates provided another key puzzle piece — strands of hair were found clutched in her hands. With the partial profile investigators pieced together, along with renewed effort put into the case, it’s possible that a complete profile could soon be created, and the Zodiac Killer may finally be put behind bars.

Forensic science gives us the tools to fight crime in a more informed manner. The forensics community is already planning the next generation of DNA analysis systems, which will be faster and more reliable. Some scientists are even working on ways to use DNA sequencing information to establish key features of an individual’s physical appearance, giving investigators a way to relate genes to the physical appearance of a potential perpetrator. Forensic science has come a long way since its first use in court, and its impacts will be felt far into the future.
COMPLEX REASONING: THE NEXT FRONTIER FOR AI

By Ryan Yang ’23

Jeopardy, chess, and Go — what do these games have in common? They were created by humans, but in recent decades, they’ve become dominated by artificial intelligence (AI). One can’t help but wonder: what else is there for AI to do?

Recently, they have been learning complex reasoning, which is critical for tasks such as computer programming and mathematical reasoning. Analogous to a human’s ability to construct complex logical structures, this is another giant step towards artificial general intelligence.

Perhaps the most famous example of progress towards complex reasoning is the recent success of OpenAI’s GPT-3, a massive 175 billion parameter neural network that can generate high-quality human-like writing. Complex reasoning for AI isn’t just limited to general text. Recently, DeepMind’s AlphaCode extended this approach to structured programming, scoring in the 54th percentile on average in a series of challenging programming competitions. Mike Mirzayanov, the founder of Codeforces, the platform upon which AlphaCode was tested, said, “I can safely say the results of AlphaCode exceeded my expectations.”

Mathematical reasoning, another problem that lately has been the focus of AI researchers, is an even harder problem to solve than programming due to the diverse number of arguments and approaches that can be taken at each step. However, in February 2022, OpenAI introduced a neural theorem prover capable of solving various mathematics problems, including some from the International Mathematical Olympiad, the top competition for high school mathematicians around the world.

How, then, are these algorithms developed to tackle these challenging problems? The studies build on the progress made by tuning the parameters of deep learning networks, a type of large neural networks. Designed to emulate neurons in the human brain, neural networks can be simply thought of as a box with inputs and outputs, with dials on the side that affect the operations inside. Then, in a process called backpropagation, the dials are adjusted until the box maps inputs to outputs to align as closely as possible with known “input-output” pairs. AlphaCode and OpenAI’s math solver took this approach one step further with an encoder-decoder transformer, a novel neural network structure that is especially good at handling long, dependent sequences of text, like the problem statements faced by AlphaCode. Locally, the encoder compresses the input data and passes it to the decoder, which expands it. Through this process, core information is filtered out and the transformer architecture maintains efficiency using attention layers.

Despite these exciting improvements, there are still limitations to how far transformers can go. In the words of Judea Pearl, winner of the 2011 Turing Award, “All the impressive achievements of deep learning amount to just curve fitting.” New techniques such as causal inference, when combined with traditional structures, are a promising way to introduce further complex reasoning structures. If successful, the advent of artificial general intelligence will fundamentally change human society, and we will be able to see the seeds of their success.
From chess-playing robots to self-driving vehicles, artificial intelligence (AI) exhibits its usefulness in all aspects of our lives. The power of deep learning in advancing data analysis and increasing cooperative performance has attracted a significant portion of today’s leading businesses to invest in AI. While such technologies augment human capabilities to an unprecedented level, they come with the potential for introducing algorithmic bias, systematic errors in an algorithm that create unfair results.

According to Dr. Andrew McLaughlin, the former Executive Director of the Tsai Center for Innovative Thinking at Yale University, “AI will drive a vast range of efficiency optimizations but also enable hidden discrimination and arbitrary penalization of individuals in areas like insurance, job seeking, and performance assessment.”

Because AI employs large data-sets to conduct iterative processing and identify underlying patterns, any bias in the training data can result in the creation of a prejudiced algorithm. Even when sensitive variables like gender, race, and sexual orientation are removed, subtle reflections of historical or social inequalities can creep their way into the final model. According to the Harvard Business Review, “Amazon stopped using a hiring algorithm after finding it favored applicants based on words like ‘executed’ or ‘captured’ that were more commonly found on men’s resumes.” Given that the algorithmic inclinations come from male-fed training data, this issue originates with the developers’ implicit patriarchal metric of competence.

Another way for bias to arise in AI is the imbalance between the various sources of training data. Especially in facial detection systems, the under- or over-representation of certain groups can often lead to an inaccurate assessment. “Labeled Faces in the Wild”, a benchmark dataset for testing the facial recognition software, includes photo samples that are 70% male and 80% white. Ms. Joy Buolamwini, a research assistant at the Massachusetts Institute of Technology (MIT) found that “facial analysis technologies had higher error rates for minorities and particularly minority women.” Such biases can cause profound operational errors for marginalized groups and lead to mistrust between the developers and the users.

The difficulty with eliminating bias in AI lies in both the inscrutable nature of the models and the limit on available data. Since AI operates without producing humanly interpretable explanations of how results are obtained and which patterns are given greater weights, the bias often remains unknown in the training stage. The discrimination will only be recognized after the model is put into practice and has made a substantial impact. In other cases, information from minority demographics is simply overlooked or scarce, leading to a distorted input and therefore a prejudiced output.

It is therefore imperative for all AI developers to supervise the automation process with great care to mitigate bias. Proper treatment of training data, thorough analysis of the algorithmic output, and the establishment of a diverse and decentralized information network are all viable approaches to improve accountability. As humans take advantage of these “smart” systems, it is imperative to maintain a high moral and ethical standard to prevent unintentional mishandling of technology.
Launched in 2016 by Tesla and SpaceX founder Elon Musk, Neuralink is a startup aiming to mesh the world of man and machine. The company has been trying to design a chipset named Link V0.9 that connects neurons in the brain to external computer chips and devices, allowing for the control of machines through thought alone.

If successful, Link will have the potential to immediately impact the lives of numerous people; for instance, people who are paralyzed or use prosthetics would be able to control their artificial body parts more efficiently using this technology. People who suffer from brain-related disorders will benefit from Link’s ability to control neurotransmitters and biochemicals within the brain to treat conditions such as depression and epilepsy, and people would be able to control electronics without physical contact, greatly reducing the time spent typing, turning on lights, or interacting with electronic devices.

However, long-term applications of this technology may affect humanity as a whole. Mr. Musk’s goal with Neuralink is to eventually integrate artificial intelligence (AI) into the human consciousness and elevate the brainpower of the entire species. The final product he envisions is a computer inside a person’s brain that would redefine human existence, creating cyborg beings that co-exist symbiotically with AI; Mr. Musk believes this is an essential step for the survival of the human species. While the ramifications of this technology may be as impactful as bonafide telepathy or the creation of collective human consciousness, the technology thus far remains quite limited.

Reports from Neuralink describe the product as a 23 mm by 8 mm chipset. Each chip can connect with around 1,000 different brain cells,
and as many as ten chips may be implanted. The wires that connect to neurons in the brain are thinner than human hair and are intricately designed to prevent permanent neurological damage. The process of installation is so delicate that Mr. Musk believes only a robot is precise enough to safely and painlessly insert the fragile machinery into the brain.

Before implanting the device, one's brain must first be scanned and imaged by a robot to locate blood vessels and vital arteries. Then, the robot will drill a 2 cm-wide hole into the skull, efficiently insert the chipset, and connect the wires to their proper places within the brain cortices. During this process, over 1,000 minuscule electrodes are placed approximately 60 microns away from nerves to pick up individual impulses. Once installed, the chipsets would need to be wirelessly charged every 12 to 24 hours through an induction coil. They would also need to be removable so that updated versions of chipsets can be installed. Electrodes within the chips may also generate their signals to control and connect to different neurons.

Although the device has yet to become a reality, considerable progress is being made. Neuralink was successfully tested on rats, monkeys, and pigs as of May 2022. While the devices installed in the brains of these animals are not entirely the same as the ones that Neuralink is developing for humans, they operate on the same principles.

Although Neuralink has the potential to revolutionize human relationships and interaction with the surrounding environment, many experts are skeptical about whether such visions are realistic. According to Antonio Regalado, the Senior Editor for Biomedicine at the MIT Technology Review, feats such as rock climbing, superhuman vision, or augmented human imagination may one day be possible with Neuralink but remain far from reality. “None of these advances are close at hand, and some are unlikely to ever come about.”

In addition to concerns about the feasibility of Neuralink, several skeptics have expressed their concerns about possible vulnerabilities: hackers could hijack people’s consciousness, insert viruses, or utilize the technology as means of spyware and government surveillance. Suppose an unauthorized person uses information from people’s minds to their advantage or hacks into one’s neurological impulses and thoughts. In that case, mind control could become a reality, compromising people’s privacy and safety. Other experts have also raised concerns about the risks of implementing Neuralink on humans, such as brain tissue damage and immune system compromise. As a result, the future of such an impactful technology remains uncertain in the face of technical, ethical, and health concerns.

Despite these issues, many people are optimistic about Neuralink and its potential to significantly improve people’s lives. Neuralink, if successful, would expand the capabilities of the human mind to unimaginable heights. While we may not see the successful connection of Neuralink with the human brains in our lifetime, the progress that has currently been made promises great future potential.
CELEBRATING THE 2021 NOBEL PRIZES IN THE SCIENCES

By James Bae ’24

Each year, the Nobel Prizes — six prestigious awards given for outstanding intellectual achievements — are awarded from a fund bequeathed by the Swedish inventor and industrialist Alfred Nobel. The Prizes are given for outstanding work in the fields of physics, chemistry, physiology or medicine, literature, peace, and economics.

Every Nobel laureate is honored with a gold medal, a diploma, and approximately one million dollars, which would be divided if there are multiple winners. Due to the Covid-19 pandemic, the 2021 Nobel Prizes were held both physically and virtually, with winners receiving their awards in their hometowns.

The Nobel Prize in Physics was awarded to three scientists: Dr. Syukuro Manabe of Princeton University, Dr. Klaus Hasselmann of the Max Planck Institute for Meteorology in Hamburg, Germany, and Dr. Giorgio Parisi of the Sapienza University of Rome. Dr. Manabe and Dr. Hasselmann were awarded “for the physical modeling of Earth’s climate, quantifying variability and reliably predicting global warming,” and Dr. Parisi was awarded “for the discovery of the interplay of disorder and fluctuations in physical systems from atomic to planetary scales.” The three scientists’ work laid the basis for a deeper understanding of Earth’s climate change and how it is influenced by human activity.

The Nobel Prize in Chemistry was awarded to Dr. Benjamin List and Dr. David W.C. MacMillan “for the development of asymmetric organocatalysis,” a molecule-building tool that encourages development in pharmaceutical research and diminishes chemistry’s impact on the environment. Dr. List is a German chemist and director at the Max Planck Institute for Coal Research in Mülheim an der Ruhr, Germany, and Dr. MacMillan is a Scottish chemist and professor at Princeton University, where he headed the Department of Chemistry from 2010 to 2015.

Lastly, the Nobel Prize in Physiology or Medicine was awarded to Dr. David Julius, a professor of physiology at the University of California, San Francisco; and Dr. Ardem Patapoutian, a molecular biologist and neuroscientist at Scripps Research in La Jolla, California, “for their discoveries of receptors for temperature and touch.” The two scientists made advanced discoveries that expanded our understanding of how the nervous system senses temperature and mechanical stimuli.

The annual Nobel Prize is an opportunity for the scientific community to coalesce and highlight research conducted by top scientists from around the world. Created in the will of Swedish chemist, engineer, and dynamite inventor Alfred Nobel, the Nobel Prizes’ mission of advancing our understanding of science to benefit humanity continues to this day.
THERE’S MORE TO GENDER THAN JUST XX AND XY

By Maya Rose Chiravuri ’23

Gender identity is becoming increasingly relevant in the 21st century. However, a lack of knowledge and education around this concept has influenced everything from laws and legislation to the way we treat others daily. So, what are the limitations of using our general knowledge of biology in discussions about gender identity?

To answer this question, we must first understand the difference between gender and biological sex. Biological sex is the combination of chromosomes, sexual anatomy, and secondary sexual characteristics that people are either born with or develop during puberty. Most often, the binary male (XY chromosomes) and female (XX chromosomes) come to mind; however, sex can be more ambiguous in individuals born with different combinations of X and Y chromosomes. According to Dr. John Achermann, Professor of Endocrinology at University College London, there is much greater diversity among males and females, and there is also an area of overlap where some people cannot easily define themselves using the binary structure. For instance, people can be born with chromosomal configurations other than just XX or XY, such as XXY, XYY, and XXX. Babies with ambiguous genitalia may have characteristics of both sexes or incompletely developed genitals. This concept of ambiguous or intersex individuals introduces the idea that sex is a spectrum with unlimited options.

Gender, on the other hand, is not defined by biological or physical traits. According to Ms. Liza Brusman from the University of Colorado, “Sex is our biology — what chromosomes, hormones, genes, sex organs, and secondary sex characteristics we have — while gender is how we think of our identity in the context of how norms function in our culture.” Gender is a self-identified construct founded on concepts of human behavior, actions, and roles based on ‘masculinity’ and ‘femininity’. According to The Pride Education Network, “gender is also a spectrum, meaning that there is a range of gender identities between and outside the categories of male and female,” such as nonbinary (an identity that is not exclusively male or female) and agender (an identity that does not have a specific gender). It is also completely valid to identify as gender non-conforming and avoid subscribing to any roles that may predefine personal traits.

Genetically, scientists have researched genes that may play a role in establishing the disconnect between the brain and the external sex of an individual. “Twenty-one variants in 19 genes have been found in estrogen signaling pathways of the brain critical to establishing whether the brain is masculine or feminine,” said Dr. J. Graham Theisen, obstetrician, gynecologist, and National Institutes of Health Women’s Reproductive Health Research Scholar at the Medical College of Georgia at Augusta University. These genes expose the brain to estrogen and are critical for the masculinization of the brain. People whose birth sex is male may have altered pathways that prevent their brains from becoming masculine, while in those whose birth sex is female, estrogen exposure may occur and erroneously lead to masculinization. Both would result in a discrepancy between an individual’s internal gender and their external sex, which can lead to gender dysphoria. “They are experiencing dysphoria because the gender they feel on the inside does not match their external sex,” explained Dr. Theisen, “once someone has a male or female brain, they have it, and you are not going to change it. The goal of treatments like hormone therapy and surgery is to help their body more closely match where their brain already is.”

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WELCOME TO THE HYPE HOUSE: THE SCIENCE BEHIND TIKTOK

By Trista LeBlanc-Serbyn ’22

TikTok is a popular social media platform that allows users to watch and post short videos to the app. It carries a variety of features, including filters, editing effects, and various “sounds” to help users create and enhance their content. Videos last between 15 to 60 seconds and are often centralized around various comedy trends, dance challenges, and point of view (POV) videos. Unlike other social media platforms, such as Facebook or Instagram, that focus more on connecting with friends, family, and colleagues, TikTok revolves around watching creators and producing your own short videos, combining aspects of both typical social media and entertainment. Since its release, TikTok has enjoyed a significant rise in popularity, with over 1.5 billion downloads as of November 2019.

So what makes TikTok so popular? Many students credited TikTok’s popularity to its humor, reminiscent of Vine, a video-sharing platform that was shut down in 2017. Apps like Vine and, more recently, TikTok, offer humor in both video content and comment sections, which is unique to Generation Z. Sesame Gaetsaloe ’21 commented that “quoting TikTok has almost become a part of our generation’s culture, in the same way that Vine did.” Social media platforms, such as TikTok, tend to create an age-specific community where a younger generation can occupy the app with their unique style of expression and humor. The majority of TikTok users belong to Gen Z, people born between 1997 and 2012, with the next most occupied user age group being Millennials, who were born between 1981 to 1996. Video-sharing networks have created virtual communities for younger generations to share the absurdist and sometimes nihilistic humor that cultivates meme culture on apps like Vine and TikTok.

As many TikTok users seem to agree, the appeal of comedy entertainment, trends, and challenges can make the app, at times, feel mindlessly addictive. Addiction to TikTok may be linked to the platform’s advanced algorithm catered to serving users’ interests. TikTok uses an artificial intelligence (AI) interface that collects information on how users interact with the stream of videos on the “For You” page. According to the Business School for the World, TikTok’s algorithm captures “not only the users’ ‘likes’ and comments but how long they actually watch each video. As the clips are very short, TikTok’s algorithms quickly build sizable datasets.” The study also deems that “this AI recipe is so effective that experts have cautioned against TikTok addiction.” Gaetsaloe agreed with the impact that TikTok has had upon her, “I end up spending two hours on TikTok when I could have been doing work, which is not ideal... My only real gripe...
with [TikTok] is how addicting it is and how much time I waste on it, which inevitably leads to my stress and lack of sleep.” For many, it’s easy to become distracted by and addicted to TikTok, as the app is designed to give users a constant stream of videos meant to keep them engaged and pique their interest. Some students even claimed that screen limitations don’t discourage their usage of the app. “It’s kind of bad. I’ve gotten to the point where I have to set a time limit on the app, and I hit it almost every day,” said Gaetsaloe. As AI technology develops, especially in the realm of social media, it’s important to be aware of its impact on our lives and the amount of time we spend watching dance videos on TikTok.

For many, TikTok has also impacted their self-image, and some argue that the content promoted by popular creators caters to unhealthy societal beauty norms. This is seen through a phenomenon called the “hype,” which describes a TikTok creator who has rapidly gained popularity. This fosters an illusionary sense of stardom, as it’s possible for anyone to be on the “For You” page. The idea of “hype” has, in many ways, created a skewed perception of beauty by reinforcing expectations that one must look a certain way to become popular. The “Hype House,” a group of people who claim to have the “hype,” consists almost entirely of creators who identify as white. Many users have created videos expressing their frustrations from the lack of representation of users with the “hype.” One group of content creators even formed the “University of Diversity” to promote the inclusion of different identities in contrast to the “Hype House”.

Nevertheless, TikTok provides ample opportunities as well. Like other forms of social media, TikTok offers a platform for users to think creatively and share their work on a worldwide scale. While AI technology can sometimes be detrimental, it also offers smart ways for people to engage with technology and create original content. An article regarding AI platforms states that “AI also helps content creators craft viral videos. It simplifies video editing and suggests music, hashtags, filters, and other enhancements that are trending or have been proven popular based on the category.” Ami Hoq ’21 commented, “In a way, TikTok had an impact on me from all different angles. TikTok is a multimedia platform and thus becomes this melting pot for a huge sample population to come together … some people use it as a substitute for Vine and make stale jokes such as ‘PSAT memes,’ but there are also creatives who use it as a medium for film, motion graphics, art, fashion, lifestyle, everything. TikTok enabled me to see all of these different artists and inspired me to create my own work.” Gaetsaloe shared similar thoughts: “I think TikTok has both beneficial and detrimental impacts on my life, as is the case with most social media. It’s the whole idea of moderation. There are some really funny content creators, and learning dances with your friends is always a nice and relaxed way to kill ten minutes when you’re bored. All in all, TikTok is just a fun app. It makes me laugh, and it lets people show their talents.”

As technology continues to develop through social media and video-sharing platforms, it’s important to recognize how it impacts our society. Through the appeal of comedy trends, dance challenges, and other creative content, TikTok has risen to popularity and continues to make changes to the social media world. The app has impacted our generation by creating a space for an age-specific community, with a unique style of expression and humor, to share content. Through its structure and use of advanced AI, TikTok may also impact teens by creating an addictive entertainment platform with carefully-tailored video recommendations. Yet, it enables users to share their creative works and understand new forms of artistic expression. Whether good or bad, it’s clear that TikTok has made its mark on our generation.
THE ENVIRONMENTAL COST OF MEAT CONSUMPTION

By Grace Wu '24

With a myriad of people sharing environmental infographics on their stories, "Go Vegetarian" and "Go Vegan" are becoming common sights on social media platforms such as Instagram and TikTok. Choate, too, has joined the act, designating Meatless Mondays in the dining hall to help reduce meat consumption. Thus, the question is posed: What are the consequences of meat consumption on the environment, and why are they important?

First, meat-based products are highly resource-inefficient. Cows, for example, must consume 16 pounds of vegetation for each pound of their flesh. It also takes 1,800 gallons of freshwater to produce a pound of beef, while only 25 gallons of water is needed to grow one pound of wheat, according to Vice News.

Besides depleting resources like water, it takes 75% more land to sustain a conventional meat-eating diet than it does to support a vegan diet, according to the international publication Our World in Data. The result of this shortage is reflected in today's allocation of agricultural land in the United States, where over 85% is used to raise animals for food.

The consequences of meat consumption are particularly visible in the Amazon rainforest, which according to Rainforest Rescue International, is responsible for producing 20% of the Earth's oxygen and is home to 10% of the Earth's fauna and flora species. Rising demand for beef is leading to deforestation as more and more land is used for cattle ranching, causing vast amounts of environmental damage.

Similarly, greenhouse gas emissions, soil erosion, and the frequency of wildfires have drastically increased due to unsustainable forest clearing techniques such as mass deforestation and forest degradation.

The expansion of grazing land not only exacerbates greenhouse gas emissions but also creates pollution through livestock. The global livestock industry is responsible for almost 64% of ammonia emissions and about 40% of methane emissions, contributing to acid rain, global warming, and loss of biodiversity.

Thus, meat consumption significantly catalyzes climate change by contributing to greenhouse gas emissions and the exhausting of resources. What does this mean for the general population? Most people are not vegetarian or vegan, and meat products are heavily ingrained in their diets. Now that the negative impacts meat consumption has on the environment are coming to light, more and more alternatives for meat are becoming available. Though it is impractical to completely refuse animal products, it would be beneficial for the environment to use some of these meat substitutes whenever it is possible. Hopefully, humanity will be able to establish a balance between meat consumption and sustainability in the near future.