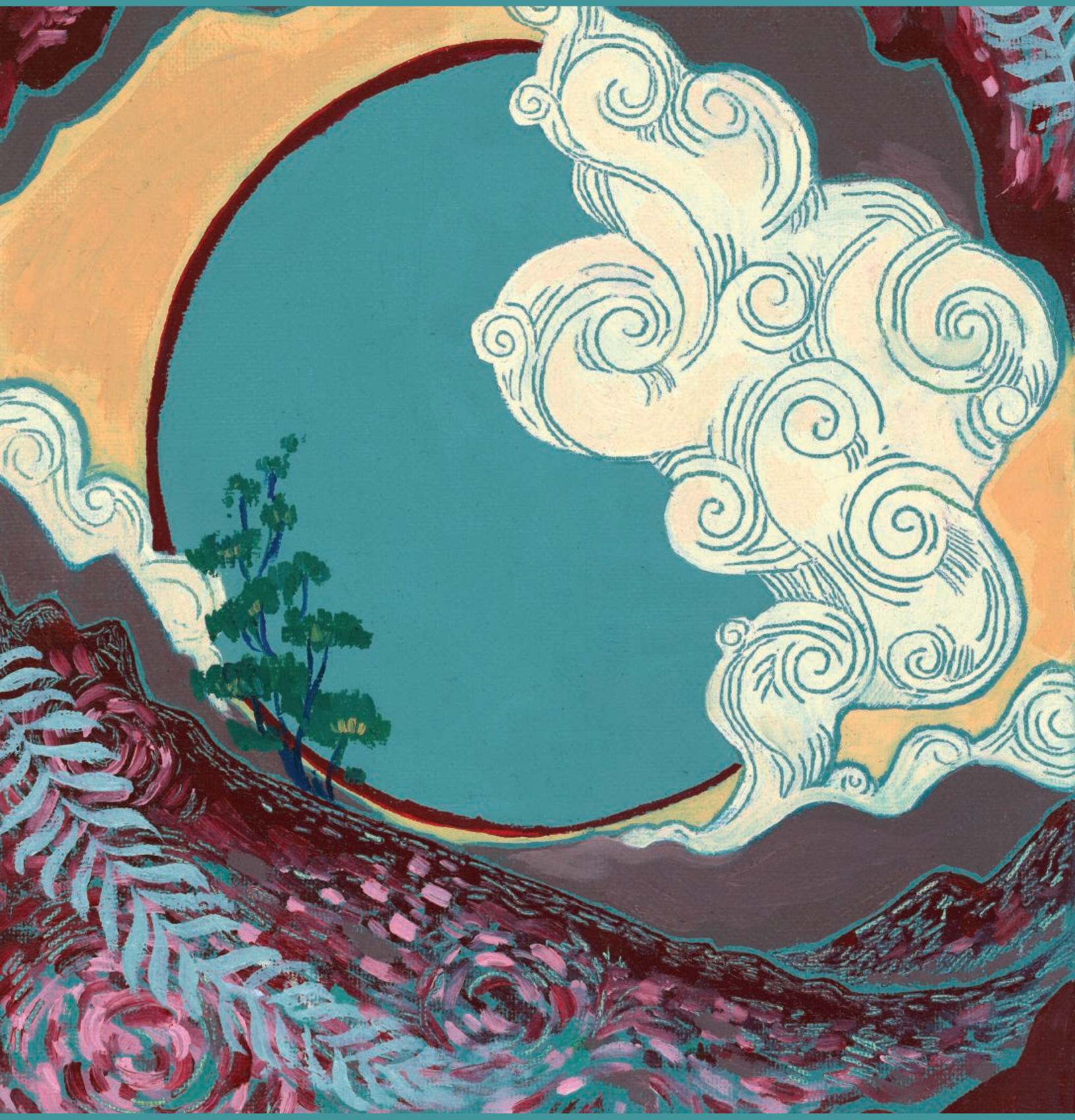
THE SYNAPSE

INTERCOLLEGIATE SCIENCE MAGAZINE ISSUE 27 | FEBRUARY 2021



THE SYNAPSE

INTERCOLLEGIATE SCIENCE MAGAZINE

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Victoria Fisher (OC '21)

Victoria Fisher is very excited to present the 27th issue of *The Synapse*. She is very proud of the hard work and dedication from every one of our contributors. This issue in particular focuses on alternatives: alternative universes, alternative conceptualizations of COVID-19, and alternatives to dairy. As the Editor-in-Chief, Victoria Fisher (OC '21) works alongside writers, editors, and artists to make this magazine possible. She hopes you enjoy the first issue of 2021 and continue supporting *The Synapse* through your readership and contributions!

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Featured Contributer

Casey Pearce (DU '21)

Casey is a senior at Denison majoring in Biology and Environmental Studies from Cleveland, Ohio. She currently serves the Denison Synapse board as our Treasurer and has contributed as a writer since her freshman year. She loves that *The Synapse* is a mixture of science and art and that it is accessible to anyone interested in understanding science, which she believes is "key to being an engaged citizen." In her free time, Casey likes hiking, painting, embroidery, and anything that lets her get outdoors, and has spent every summer since freshman year traveling. She is also a senior fellow for the Environmental Studies Department, as well as a member of Phi Society, and Denison University Biology Society (DUBS). After graduating, Casey hopes to work in environmental education and promote conservation.

Featured Contributer

Elizabeth Rigby (OC '22)

Elizabeth is a third-year at Oberlin majoring in Chemistry and German from Helena, Montana. She currently serves as a permanent content editor for the magazine and edited ever since her first year at Oberlin. Elizabeth loves that *The Synapse* is a space where students can share interesting science with their peers, particularly because communicating science is such an important skill. During her quarantine, Elizabeth has dived into the world of *Star Wars*, watching many of the movies as a substitute for socialization. She sees the world as a puzzle, and is passionate about finding and putting those pieces together. While she does not yet have any firm plans for after college, she loves spending time on the bowling team, bike co-op, and playing board games.

Contents

Smaller Families and Smaller Replacement Rates:

An Investigation into the Declining U.S. Population

Written by Jennifer Clancey
Illustrated by Athina Apazidis

Around 250 babies are born in the world every minute. These numbers, reported by The Guardian, lead us to believe that the birth rate and population are infinitely growing. But is this view really accurate? Two major data-collecting organizations, The World Bank (WB) and the United Nations (UN), have interesting answers to this question. On the surface, data show an expected increase in the world population over the next 50 years. However, looking closer at the number of births per family in the United States (U.S.) may reveal a different picture for the next half-century.

It is important to understand replacement rates to have a grasp of the significance of fertility numbers. According to a CNN report, a replacement rate is defined as the ability for a couple's offspring to replace them. So, let us say a made-up couple, Jess and Joe, have two children. This couple would be right at the level of the replacement rate because their children will make up the population difference when their parents pass away. Cilluffo and Ruiz of Pew Research Center note that the prime replacement rate is about 2.1 births per woman. This number would allow the population to maintain a stable size.

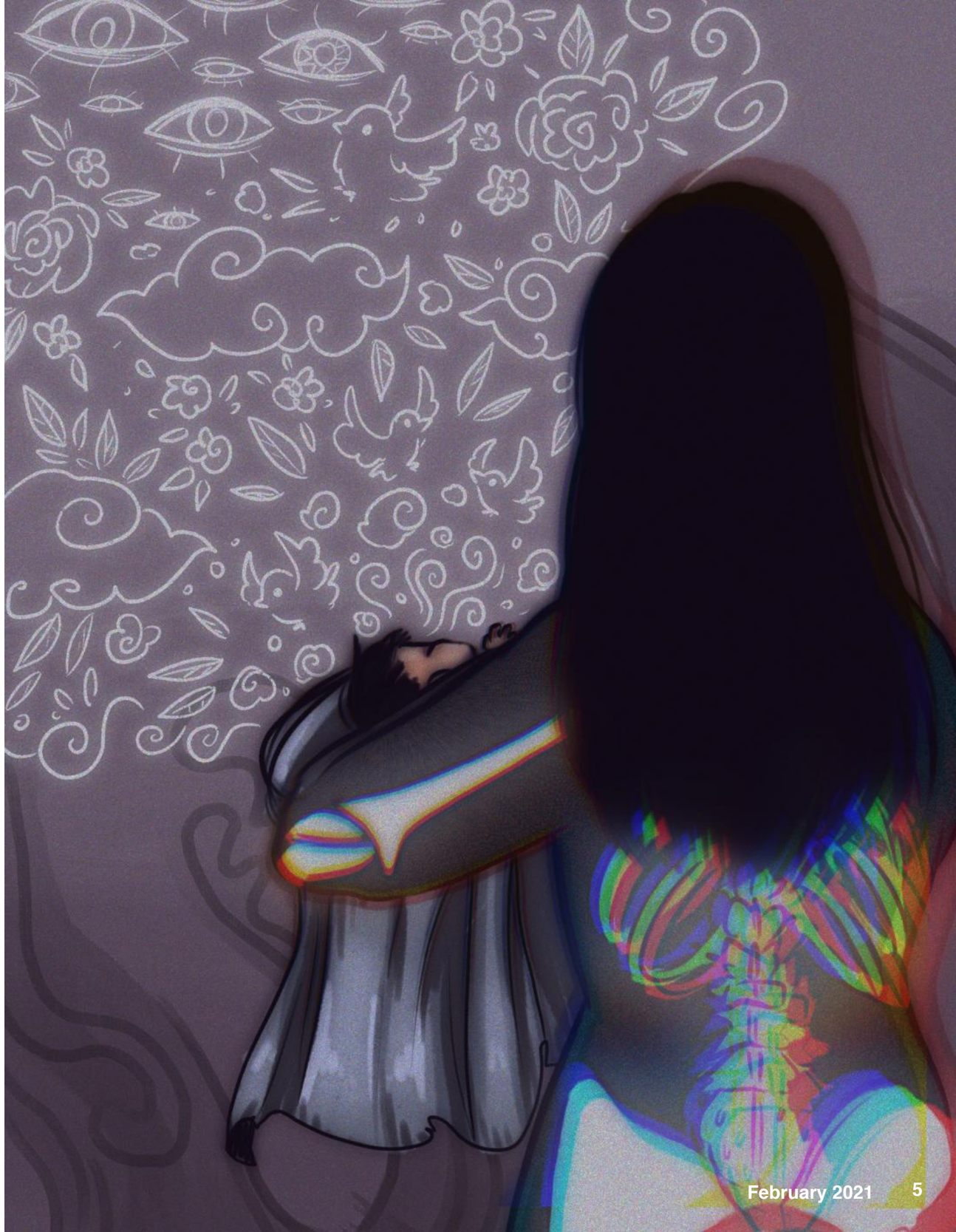
According to the Center for Disease Control (CDC), the U.S. currently has a replacement rate of about 1.7 births per woman. Moreover, this number does not show any sign of increasing soon. Social changes such as women pursuing higher education, more consistent use of birth control, and women focusing on careers have caused a later start to families in the U.S. According to the National Vital Statistics Report (NVSR) by the CDC, the mean age of a mother's first birth was 26.9 years in 2018. The NVSR accredits this to mothers having fewer births in their 20s and more in their 30s and 40s. However, this is not an uncommon occurrence, according to the World Bank. In fact, the U.S. is likely following in the footsteps of countries like Japan, Australia, and Italy, in which people are starting families at an older age. As expected, this later start causes smaller replacement rates: Japan with 1.4, Australia with 1.7, and Italy with 1.3.

The birth rate in the U.S. has steadily decreased in the last 15 years to about 1,729.5 births per 1000 women, resulting in the aforementioned replacement rate of 1.7. This decrease in replacement rate stayed relatively the same across races from 2017 to 2018. The decline in the replacement rate has caused some researchers to worry about its social implications in the next half-century. For instance, they have raised questions regarding how an only child will take care of elderly parents and how a smaller generation in the population may not be able to fill the workforce. In a report for National Center for Biotechnological Information, Phillip S. Morgan notes that this shift will result in "rapidly aging populations and possible country-level population decline." However, this is not necessarily a bad thing. In the highly populated countries in Europe and North America, population decline will reduce and slow the negative outcomes of overpopulation.

Additionally, starting families later and lowering the replacement rate have many benefits. For instance, having fewer children also allows children to have better access to resources. Because women are increasingly involved in the workforce, there is a higher chance a woman will have a stable career by the time she has her later birth. There may be more of a safety net for the child in this case. When the safety net is reserved for one or two children, the child will not cause as much financial and energetic strain on the parents. Morgan sees this as an outstanding benefit to fertility decline; he says, "children are costly in modern contexts: the fewer children one has, the better" the family is.

By having fewer children, a shift in parenting style and family relationships can take hold. A parent is able to give more attention to their child and spend more time creating trusting relationships with them. The choice of having fewer children in modern days, understandably, holds much more weight.

Conversations surrounding population changes frequently center on how the exponential growth of the global population will strain Earth's limited resources. More recently though, as certain countries incentivize having fewer children and starting families later, the conversations have shifted to how we can quell our fears of a declining population. However, there are numerous benefits enjoyed by households that have fewer children, illustrating that declining birth rates may not be as problematic as we might have previously conceived it to be. Encouraging families to be smaller by increasing access to birth control and implementing accessible family planning programs may be the next step in combatting overpopulation. • • •



Possible Worlds

The Same Modal Logic Which Underlies Our Computational Modeling Systems Also Allow Us to Make Sense of Language

Written by Julian Lee-Sursin
Illustrated by Evelyn Lazen

It is common to hear people say, "If there had been less traffic, I would have gotten to work on time!" or, "If I hadn't waited until the last minute to study, I would have gotten a better grade on my exam!" These kinds of sentences are called modal claims because they describe a way in which things could have been. Modal reasoning often underlies our language and allows us to make sense of notions like possibility and necessity.

In addition to language, modal logic has practical applications to logic and computer science. For example, model checking uses temporal logic, a type of modal logic, to construct a reactive system that can model infinite words as a linear structure. Modal logic is also used to make sense of set theory. Set theory is a mathematical language that describes entities, or sets, that contain a finite or infinite number of members, used for modeling and inferencing in statistics, sociology, and social psychology. However, let us revisit the semantics of modal language. Take this example: "If there had been less traffic, I would have gotten to work on time." This is a basic claim in the form of "if P, then Q," known to logicians as a modus ponens. What differentiates this sentence from a normal modus ponens is the nature of P, "if there had been less traffic." Consider that whoever uttered the first sentence was, in fact, stuck in traffic, which is why they were late. In other words, P is referring to an event that did not take place in the actual world. This is what makes this modus ponens modal.

Nevertheless, one might ask whether it makes sense to talk about something that is not actual; what is P referring to? This is a valid semantic concern. In the field of linguistics, it is crucial that sentences refer to something that is actual. So, how do we square this with modal claims? Modal logic is the fundamental axiom of talking about notions of possibility, which is of great utility in many fields, so it is worth preserving its semantic validity if we can find a way to do so.

What is Modal Realism?

A philosopher named David K. Lewis proposed his theory of Modal Realism as a way to make semantic sense of modality. The theory asserts the following, essentially referencing the concept of parallel universes:

1. A number of possible worlds exist.

2. These possible worlds are actual; they exist and are as real as our own world; they are the same kinds of things as our world.

3. Each possible world is irreducible. There is no other kind of thing that possible worlds are composed of.

4. Each possible world is causally and spatiotemporally isolated.

5. Actuality is indexical. When one refers to the actual world, the word "actual" is being used to index one possible world (out of the set of possible worlds) as world one is existing in.

These propositions constitute a sufficient definition of modal realism for the purposes of Lewis' paper and accurately represent his theory. However, these premises also have utility in understanding modal language.

Take note of proposition two, that every single possible world is the same kind of thing. This is important because we are not inflating our ontology with many different kinds of things. Although modal realism does multiply entities, these entities are the same kinds of things as our own world. This is preferable to positing a new kind of entity, as it causes many problems to do so. For example, one could say that modal statements refer to unactualized things that are possible, e.g., unicorns exist as an entity that could exist or that could have possibly existed, but simply does not happen to exist. This alternative, however, is positing the existence of a new kind of uninstantiated object, which begs the question as to what the nature of that kind of object is. Additionally, one might reject that an object which is uninstantiated does not exist. Thus, proposition two is crucial because positing the existence of multiple entities is much less problematic than positing a new kind of entity.

Proposition four states that all possible worlds are isolated, both causally and spatiotemporally. This proposition is necessary because if you could interact with another world, that world would just be a part of the world you are in. This proposition also helps us understand that Lewis defines a world as the totality of all causally and spatiotemporally related parts of a given system.

Proposition five is useful for clarifying terminology. Since all possible worlds are equally real, the use of the term "actual world" does not refer to a world that is more real than another, but rather is used to index. That is, the "actual world" refers to the world in which one is instantiated as opposed to a different possible world.

So, why should we accept the theory of modal realism? In his book *On the Plurality of Worlds*, Lewis says that one reason to accept modal realism is its utility with regards to modal logic. He points out (as we have already established) that in order for a modal claim to be sensical, the claim must be referential. Take the following counterfactual as an example: "Alan could have baked chocolate cake last night." Let us assume that this counterfactual claim is true; Alan had all the prerequisite ingredients and access to the equipment necessary to bake a chocolate cake, and he truly did possess the ability to make a cake. However, one could ask what does the term "chocolate cake" refer? Alan did not actually bake a chocolate cake. There is no chocolate cake existing now to which the term "chocolate cake" refers. What is it referring to then? One might say it is referring to a hypothetical cake that could have existed, but this is dodging the question. A hypothetical cake does not exist in actuality, otherwise, it would not be a hypothetical cake. Yet, we are inclined to believe that that counterfactual statement has a truth value.

Modal reasoning often underlies our language and allows us to make sense of notions like possibility and necessity.

Lewis believes the only way to resolve this problem of referentiality is to say that the chocolate cake is not hypothetical. According to modal realism, the claim "Alan could have baked chocolate cake last night" is equivalent to saying that in a different possible world, one with laws of nature identical to those of our own world and where all prior events leading up to the claim are identical to all prior events in our world, Alan did bake a chocolate cake which truly exists and is just as real as any object in our own world. Thus, the term "chocolate cake" does refer to something real. In this way, modal realism allows us to make sense of modal logic.

In conclusion, adopting modal realism as a tenet of one's ontology allows one to make sense of modal logic. This is useful not only in terms of justifying one's semantics, but also for epistemologically grounding the methods used in computer and statistical modeling. • • •

Race for Post Quantum Cryptography

Quantum Computing and Cyber Security

Written by Ishaq Kothari
Illustrated by Averly Sheltraw

Since its birth in the 1940s, computing has played a significant role in our lives. It encapsulates areas ranging from personal messaging to banking. The widespread use of computers has made it necessary for us to secure our transactions and communications from the general public to ensure our privacy. To do so, computer scientists have adopted cryptography: the study of methods for secure communication. Cryptography has been present in society since the Roman Empire. Generals, such as Julius Caesar, would encrypt their messages by switching the letters in communications. Today, cryptography methods have become more advanced in order to deal with the challenges of modern computing.

The most popular method of encryption is the Rivest-Shamir-Adleman (RSA) public key, which creates a code for a message by using the factors (numbers that multiply together to get a specific number) of an incredibly large number to create a new coded message. These methods of encryption are known as "trapdoor functions" as it is easy for a computer to create new coded messages but difficult for a computer to break the code, just as it is easy to enter a trapdoor but difficult to get back up. RSA functions are hard to decode because it is difficult to solve to determine the factors of a number that is 617 digits long. This method allows for messages to be easily decoded if the intended recipients know the prime factors (the smallest possible numbers that can be multiplied together to get a specific number) but difficult for any intruder who only knows the public key to decrypt.

> Cryptography has been present in society since the Romans with generals such as Julius Caesar encrypting their messages by switching the letters in communications using a secret key.

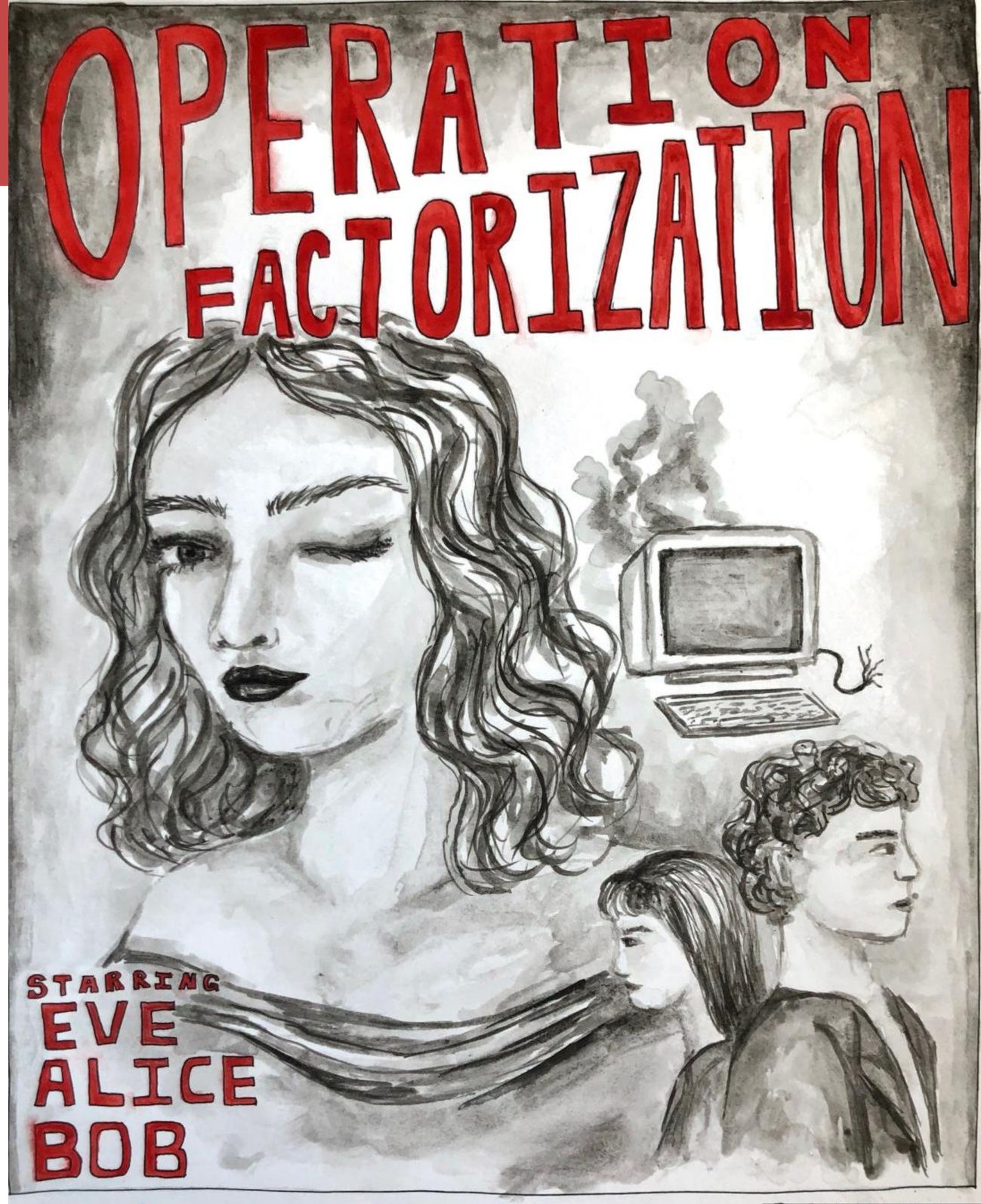
As of now, the RSA public key method of encryption is very secure, with computer scientists estimating that it would take over a trillion years for a classical computer to crack an RSA key. Due to its security, variations of RSA encryption are used for the most secure data from financial transactions to military intelligence. However, recent developments in a field of computing known as quantum computing may threaten the security of our encryption methods.

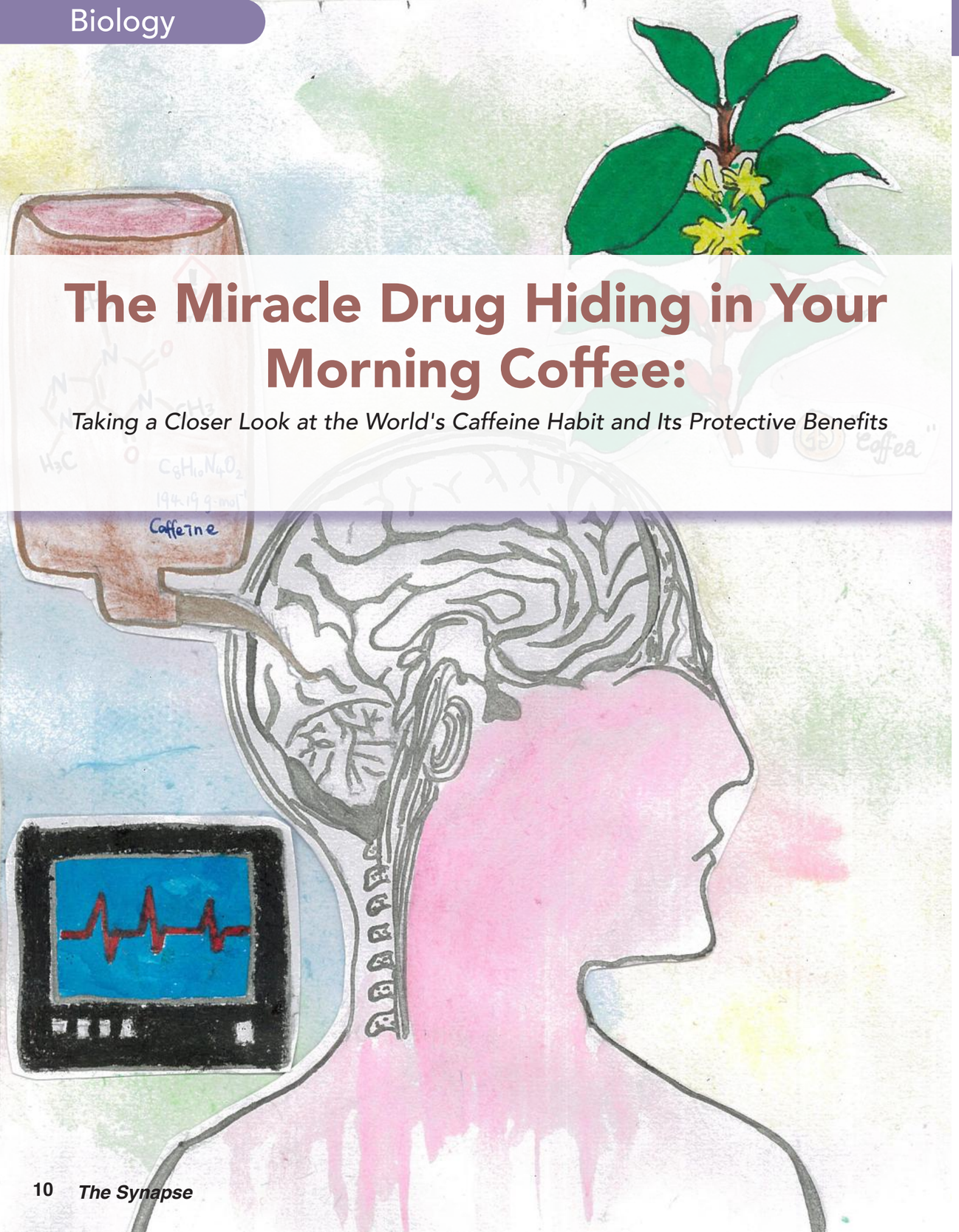
Quantum computing is a branch of computing that uses the multiple states of subatomic particles to perform multiple computations at the same time. Classical computers perform computations in a binary state where each computer bit is composed of a value of either zero or one. Quantum computers, however, use qubits. Qubits can provide far more information by representing multiple combinations of different binary states at the same time through a phenomenon known as quantum entanglement. It is unlikely that quantum computers will ever make it into the consumer market as the machines are incredibly delicate. Quantum computers require near absolute zero temperatures to prevent decoherence, where the subatomic particles fall out of quantum entanglement before the computation is completed. Due to its sensitive nature, quantum computing is most likely to be used to solve computational problems in isolated locations.

Quantum computing has recently become a threat to cybersecurity due to the potential for quantum computers to crack encryption methods such as RSA keys. Unlike classical computers, which would never be able to factor numbers of the magnitude of those used for quantum computing, it is estimated that a 20 million qubit quantum computer could decrypt an RSA-2048 key, which uses a number between 22047 and 22048, in under eight hours. The potential for quantum computers to decrypt such large numbers comes from the discovery of an algorithm known as Shor's Algorithm, which can solve for the factors of large numbers by evaluating the length of a sequence of numbers to analyze where the prime factors are. This applicability of the algorithm was first proven in 2001 by IBM, where a quantum computer with seven qubits factored 15 into three and five. The applicability of the algorithm to RSA keys seems difficult now, seeing as the hardware necessary for computing the algorithm for larger factors is not present at this time, given that the largest quantum computer has 65 qubits — far from 20 million.

Although researchers still estimate that it will take at least two decades before we have quantum computers that can be a threat to RSA encryption, groups such as the United States (U.S) military and financial institutions have already begun to search for quantum-resistant methods of encryption. The U.S. military held a competition known as the Post Quantum Cryptography Standardization, where researchers devised new algorithms that are difficult for quantum computers to solve. The most popular and effective methods are lattice problems. Lattice problems operate by taking a vast grid of line segments with a particular orientation and plotting a path within them. The two endpoints would be known, however, the specified path is only shared with the recipient and sender of the message. These problems are impossible for either quantum computers or classical computers to solve. Additionally, they are easy to generate, making them prime candidates for post-quantum computing.

Quantum computing provides a dilemma for the scientists and policymakers of our generation. This evolving technology will be monumental for our progressively virtual world by providing a whole new realm of computational power. However, the advancement of quantum computers poses serious threats to the digital walls we have built to protect society. As we unravel the wonders of quantum-computing, we must also stay vigilant and derive new ways to guard ourselves. • • •





The Miracle Drug Hiding in Your Morning Coffee:

Taking a Closer Look at the World's Caffeine Habit and Its Protective Benefits

Written by Anna Slebonick
Illustrated by Norah Han

Whether it is consumed in coffee or laboratory-produced energy shots, people across the globe utilize caffeine for its energizing effects. What most may not realize is that caffeine is classified as a psychoactive drug, specifically as a central nervous system (CNS) stimulant. Like any other drug, caffeine can provide many benefits. However, it is possible to ingest too much and feel negative side effects, though these are not long-term detrimental effects. What exactly are the effects of caffeine on the body? Similar to other CNS stimulants, caffeine increases one's blood pressure, heart rate, and alertness. When taken in moderate amounts, such as drinking one cup of coffee or tea, caffeine can maximize post-exercise recovery and even help protect against neurodegenerative diseases and cancers.

Caffeine is an adenosine receptor antagonist, meaning that it binds to adenosine receptors in the brain and blocks adenosine from signaling to nerve cells in our brains. Adenosine is a CNS depressant naturally produced in the human body, and it causes the opposite effects of caffeine. Normally, when adenosine binds to its receptor, these nerve cells slow their activity, causing us to feel tired. When caffeine binds to adenosine receptors, the nerve cells in our brain speed up their activity and activate the beginning of a biochemical pathway. The pituitary gland, located near the middle of the brain, senses this increase in neuronal activity. Then, it signals the adrenal glands to release adrenaline. Adrenaline constricts blood vessels, signals the liver to release glucose into the bloodstream for energy, and speeds up the heart's rate of contraction. The connection between caffeine and adrenaline explains why most of us feel more alert after consuming a cup of coffee. The simple binding of a molecule to a receptor signals a whole cascade of events, resulting in a noticeable physical sensation.

Consuming a large amount of caffeine at one time can make these effects last longer to a degree, but too much will cause adverse effects. The U.S. Food and Drug Administration (FDA) recommends limiting caffeine consumption to less than 400 milligrams a day, but everyone has a different threshold. One's caffeine limit depends on several variables, including sex, weight, height, and medications taken. When too much caffeine binds to

> In such an extreme flight-or-fight mode, someone could be sitting and doing homework, but their body can feel like it's ready to run a marathon.

adenosine receptors, the pituitary gland senses an abundance of neuronal activity, and, consequently, a massive amount of adrenaline can be released. When adrenaline floods the body, anxiety, heart palpitations, spiked blood pressure, dizziness, nausea, and muscle tremors can occur. In such an extreme flight-or-fight mode, someone could be sitting and doing homework, but their body can feel like it's ready to run a marathon. Doses under the FDA's recommendation are mostly tolerable, but excessive amounts can leave a person feeling ill for the day. Luckily, caffeine has a half-life, the amount of time it takes for half of a compound to degrade, of about six hours, meaning its effects are relatively short-lived. After caffeine dissipates from the body, the biochemical pathway that signals the release of adrenaline shuts off, and the negative, untoward effects wear off. Though there is a potential for overconsumption, caffeine has a wide range of positive effects on biological processes, depending on the type of tissues, cells, and molecules it interacts with.

Interestingly, research has shown caffeine can alter the progression of multiple diseases using different biological mechanisms. An article by Hamadeh and Kolahdouzan discussed

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caffeine's protective properties against Alzheimer's and Parkinson's disease, two debilitating neurodegenerative diseases. When adenosine binds to its receptors in the brain, the activated biochemical pathway creates reactive oxygen species (ROS), which are associated with neurodegeneration. When given in doses of three to five milligrams per kilogram of body weight, the researchers project that caffeine inhibits the synthesis of ROS. Thus, by blocking adenosine from binding, the presence of caffeine may lead to decreased levels of ROS in the brain. To support this idea, Hamadeh and Kolahdouzan found multiple studies showing that long-term coffee drinkers had a decreased risk of developing Alzheimer's. One study showed that those who consumed three to five cups of coffee on average had a 62–64% decreased risk of developing Alzheimer's compared to those who consumed zero to two cups a day.

Caffeine additionally may be able to combat gastric cancer, albeit through different mechanism. Liu, Tang, and Zhou investigated human gastric cancer cells' response to caffeine in vitro (not in a living organism itself). Compared to cells treated with a control solution, those treated with caffeine displayed less growth and division, or proliferation. The researchers determined that, in certain doses, caffeine prevents gastric cancer cells from proliferating and also stimulates apoptosis, which occurs when cells control and plan their own death. While caffeine is not an absolute treatment for cancer or Alzheimer's disease, this type of information may push scientists towards developing new, more effective treatments utilizing caffeine.

From exercise performance to Alzheimer's disease, scientists have found a broad range of applications for caffeine. Caffeine's versatility and potential are highlighted by how the molecule can prevent healthy brain cell deterioration, as well as stimulate controlled gastric cancer cell death. As research progresses, caffeine may emerge as the forthcoming answer to unsolved health problems. In the meantime, drinking a cup (or three) of coffee or tea every day may provide unforeseen, long-term health benefits in addition to its energizing effects. • • •

Authentic Animal-Free Dairy

Going Vegan Made Easier by Milk-Producing Bacteria

Written by Sydney Rosensaft
Illustrated by Havisha Bache

Environmentally conscious plant-based dairy alternatives do not compare with the distinct taste, smell, and texture of animal cheese. Unfortunately, traditional animal-based dairy production negatively impacts the environment due to its energy and water consumption and carbon emissions. Environmentally aware individuals are torn between ecologically friendly products and authentic dairy. To resolve this issue, start-up companies are working on an animal-based dairy alternative that bypasses the use of livestock. By growing synthetic milk-producing bacteria to mimic those in a cow's intestines, researchers obtain real dairy cultures without causing a harsh toll on the environment.

Dairy's distinct taste, texture, and smell are due to the chemical structure of milk proteins, including the proteins casein and whey. Certain amino acids in milk protein contribute to the specific taste when a mouth enzyme, peptase, breaks down protein chains. Small fatty acid molecules also add to the flavor by forming volatile compounds. Additionally, our taste buds detect acidic calcium and phosphate ions.

One beloved dairy product that has been particularly difficult to mimic is cheese. Cheese's odor comes from triglyceride fats that are broken down by another enzyme, lipase. Another unique factor of cheese is its gooey texture when cooked and how it melts in our mouths. This unmistakable texture is achieved because of the dairy fat that is partly solid, partly liquid, and constructed of discrete particles that melt at different temperatures. Plant-based dairy alternatives use plant substances such as vegetable oils and nuts. While these ingredients are more sustainable to produce because they require fewer resources, the taste and texture of non-dairy cheese is compromised. It creates a dilemma for environmentally mindful individuals: do they enjoy authentic cheese or sacrifice milky deliciousness for the environment?

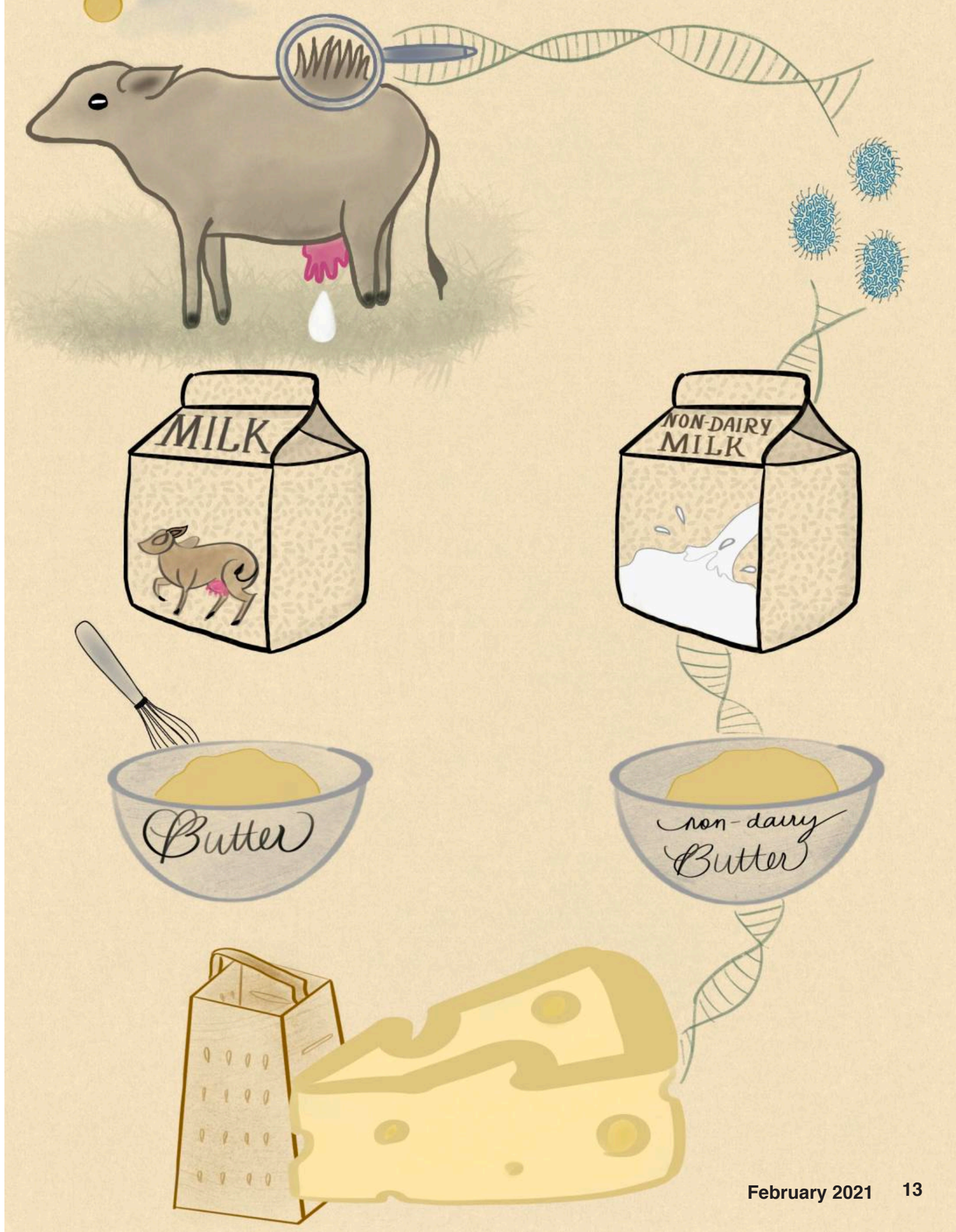
Fortunately, scientists have found a way to produce milk proteins and dairy fats without expending resources on dairy herds, accomplished by taking advantage of the fermentation process. Naturally, microorganisms break down glucose anaerobically (without oxygen), and use the energy for chemical activities. By giving the microorganisms milk-protein-producing genes, they will produce our desired milk molecules, including casein, whey, and triglycerides, as they eat the sugar. The basis of this idea is that all living organisms can read the same deoxyribonucleic acid (DNA) molecules comprise genes, which are essentially a form of encoded instructions to construct specific proteins. If we input the dairy-producing instructions into microorganisms, they will know how to read it and produce milk protein. Getting these milk protein genes from cows is easy: farmers can simply pluck a hair or do a cheek swab. Once the genes are obtained, scientists insert them into the DNA of microorganisms, which can be bacteria, yeast, or fungi. The microorganism farms are kept in big "fermentation tanks" at an optimal temperature, pH, and salinity to maximize the amount of milk protein produced.

Since the fermentation tanks are maintained as closed systems, the microorganisms produce milk proteins that are pure and safe, which qualifies them to be "Generally Recognized as Safe" (GRAS) by the U.S. Food and Drug Administration (FDA). The synthesized proteins are identical to those found in real milk, yet since there is no contact with an animal's gastrointestinal tract, the milk is lactose-free and cholesterol-free. All of the lactose and cholesterol that is normally found in dairy is contamination from an animal's insides. Because of the purity and uncontaminated nature of the bacteria-grown milk, the dairy contains more nutrition per gram. While this "fake" dairy performs all the same processes and can taste the same as distinctly recognizable cheese, the environment is not unfairly compromised for the benefit of humans.

A few start-up companies are working on making dairy-alternative products with these microorganism gene-altering techniques. In 2014, Perfect Day was founded by a vegan who was disappointed with the soy-based vegan cream cheese options in Boston. Since the fake cheese was missing the distinct milk proteins, the texture was runny and it tasted like melted plastic. With the help of another disappointed vegan, this vegan partnered with New Harvest, a group of scientists working to make meat without animals. Later, the group collaborated with Horizon Ventures to found Perfect Day. Another company, Change Foods, is dedicated to a similar purpose: authentic-tasting dairy alternatives. Similar to Perfect Day, their milk proteins are lactose-free, hormone-free, and hypoallergenic because they are grown by bacteria. Since the bacterial fermentation tanks require less upkeep, Change Foods' factories use 98 percent less water, 65 percent less energy, and 84 percent less carbon dioxide equivalent emissions than traditional dairy farms.

Both of these companies were initially worried about how the public would receive alternative dairy products. People are passionate about the authenticity of their cheese and the creaminess of their ice cream. However, since the bacterial milk proteins are fundamentally the same as regular dairy products, the taste is unmistakably similar, and the public has been very passionate about supporting these businesses. In 2019, when Perfect Day's products were ready for launch, thousands of pints of dairy-alternative ice cream sold out in just 11 hours.

Although these companies have received a lot of positive press, eager investors, and enthusiastic consumers, there is a major concern lingering: expanding the companies and the number of fermentation tanks will be costly. However, the increase in the world's population has led to less land and water to maintain dairy herds, so it is not sustainable to continue to consume regular animal-produced dairy. This, coupled with a higher demand for food, the human population will not be sustained on the old mechanism of dairy farming. Given society's desperateness, more people are becoming aware of the negative effects of traditional dairy farming and working on environmentally-friendly alternatives.



Fire Regimes of the Anthropocene:

The Influence of Climate Change on a New Era of Wildfires in the American West

Written by Eric Schank
Illustrated by Holly Yelton

For weeks in September 2020, massive wildfires on the west coast gave rise to smoke plumes so vast that they were visible from satellite images and blocked out the sun in most of California, Oregon, and Washington. Amidst the general unrest of 2020, politicians in the midst of heated discourse fueled by misinformation once again failed to adequately address the realities of catastrophic wildfires in the West. Every year, wildfires rage across North American wildlands, reigniting a highly politicized debate in the United States (U.S.) about the relationship between climate change and wildfire season. Climate change is not the reason there are wildfires in the United States, or anywhere for that matter. Periodic wildfires are essential to the natural cycles of many ecosystems around the world. What is concerning about recent wildfire seasons is the increased prevalence of large wildfires that often burn with greater intensity. Overwhelming evidence indicates that climate change is responsible for this trend. As this is likely to continue, a major shift in wildfire policy is necessary to mitigate the devastating ecological and socioeconomic impacts on the western U.S.

Large wildfires are on the rise in the United States, with deadly consequences and rising costs for the low-density communities they most often affect. In the last five years, the U.S. federal government spent an average of $2.3 billion per year on wildfire suppression, up from the ten year average of $1.8 billion per year. Despite these efforts, wildfires' total annual acreage reached levels unseen since the mid-1950s, when wildfire suppression became widely implemented. Each of the last three decades has had a significantly higher average wildfire acreage than the preceding decade. However, the total number of wildfires has actually gone down in the same period rather than increasing, meaning that wildfires are larger on average, especially in the West. In fact, approximately 94 percent of the total area burned was in the West, while that region accounted for less than 53 percent of the total number of wildfires in 2020. As of October 31st, just over 47 thousand wildfires, the lowest number of wildfires since 1984, had scorched approximately 8.5 million acres of U.S. wildlands in 2020, easily exceeding the ten-year average of 6.4 million acres burned a year. California alone accounts for an unprecedented 3.1 million acres burned in 2020, with five of the six largest fires in its history and the most extensive area burned in the state on record. Although certain aspects of the 2020 wildfire season are record-breaking, the year was not a statistical outlier but rather a part of a multi-decade trend of increasingly large wildfires.

Divisive rhetoric and misinformation may dominate headlines about climate change, but consensus on climate change and its potential impacts on the wildfire season has been long established within the scientific community. With great certainty, the Intergovernmental Panel on Climate Change (IPCC) has shown that radiative forcing resulting from the accumulation of greenhouse gasses (GHG) in the atmosphere has significantly contributed to climate change over 30 years of accumulated scientific data. As predicted by the IPCC as far back as 1990, arid and semi-arid regions of the world have experienced an upward trend in the severity and prevalence of large wildfires.

The mechanisms by which climate change affects wildfires are varied, but it is apparent that increasing temperatures in the West have contributed significantly to conditions that are more conducive to the spread of large wildfires. Species that were once successful in large swaths of the western U.S. are now unable to survive in much of that land due to a rapid shift in average regional temperature ranges. Further exacerbating this problem, the increasing temperature range also brings invasive species further north, damaging or otherwise out-competing native vegetation. Both these impacts contribute to a higher death rate among native plant species, causing an increase in flammable debris. This is a process known as fuel loading. Higher temperatures also facilitate evapotranspiration, the loss of overall moisture content in vegetation. This means that live vegetation ignites more easily. Observed increases over the last 30 years in fuel loading, fuel aridity (the drying out of forests and ecosystems), and larger, hotter wildfires in western U.S. forest ecosystems are likely to continue.

Atypical weather patterns responsible for the particularly damaging wildfires in California may be indicative of a new trend that may compound the impacts of rising temperatures. In 2020, large wildfires in California were linked to 14 thousand lightning strikes that occurred over a three-day period in August. The high-pressure weather systems that hover over the West are responsible for the prevalence of dry thunderstorms and contribute to the dry conditions conducive to wildfires. Human-caused wildfires are typically far more common in California, so the fact that lightning resulted in such massive wildfires is unusual. However, recent studies suggest that increased surface temperatures have altered the air circulation between the equator and the subtropics, known as the Hadley cell. The descent of air into the subtropics, responsible for dry, high-pressure systems, has expanded its range further into the temperate zone in the last several decades. Along with reducing cloud cover, exacerbating droughts, and extending the wildfire season, this trend could have contributed to the unusual string of lightning strikes. If that is the case, the record-breaking 2020 wildfire season in California could become a common occurrence, with the number of large wildfires continuing to increase.

Frequent, large wildfires destabilize ecosystems and are responsible for many structural losses, resulting in tens of billions of dollars in damage annually. Many of these large wildfires keep burning until snow or rain puts them out. As higher temperatures contribute to a longer dry season, these wildfires have more time to spread unimpeded. The increased prevalence of such wildfires will contribute to accelerated erosion, additional carbon emissions, and an increase in periods of hazardous air quality. Moreover, these massive wildfires burn with greater intensity, and conventional fire suppression tactics have proven to be increasingly ineffective. Firefighting is necessary when wildfires pose an imminent threat to human health and infrastructure. However, toxic fire retardants and habitat fragmentation caused by fire blocks are incredibly damaging to the ecosystems' health and impede their ability to recover after a fire. Because the U.S. Forest Service quantifies the productivity of forests in terms of timber available for extraction, the potential deaths of firefighting personnel and disruption of ecosystems are considered acceptable risks to protect corporate logging interests.

Despite the devastating socioeconomic impacts of large wildfires in the West, fire is essential to the basic functioning of arid ecosystems – of which the West is largely comprised. Due to a lack of available moisture in the air, organic matter does not readily decompose, contributing to a buildup of highly flammable biomass over time. Fire regimes, the natural patterns of wildfire size, severity, and frequency within a given ecosystem, directly contribute to species composition and the health of an ecosystem by killing off maladapted species and periodically cycling stagnant nutrients back into the soil in these arid regions. When smaller fires occur and the succession of species is permitted to resume naturally, the surviving vegetation maintains soil structure while creating more resilient, varied ecosystems.

In the U.S., a harmful conservationist framework focused on protecting logging interests informed an ecologically-flawed model of forest management, in which intense fire suppression was applied universally to all wildlands for almost a century. This also included commercial thinning, post-burn clearing, and conventional clear-cutting practices. These practices fail to mimic fire regimes and are actually known to compromise otherwise wildfire-resistant forests' natural structure. Although thinning may seem like a practical solution to the burn deficit, the large, healthy trees that are cleared are also those most likely to survive a fire. This creates a negative feedback loop that strips nutrients from an ecosystem over time. In addition to contributing to erosion and impeding recovery, the controlled "re-stocking" after clear-cutting and post-burn clearing creates areas of densely packed single age trees that are more susceptible to large crown fires.

While it is still early to conclude the extent to which climate change will alter fire regimes, it is clear that human adaptation to large wildfires is unavoidable in the coming decades. In recent years, prescribed burns have been implemented under safe conditions to address the cumulative burn deficit and fuel buildup resulting from overzealous fire exclusion in backcountry areas. Though prescribed burns are applied unevenly due to the hoops and ladders of conflicting state and federal policies, they remain an effective tool to reduce excess fuel loading. A successful wildland management strategy would include wildfire management through close monitoring of remote fires and a robust application of supplementary, prescribed burns, while only engaging suppression tactics when fires pose an imminent threat to human life or infrastructure.

COVID-19 Vaccine Development

Why Does Vaccine Development Take So Long — and How is it Being Sped up for COVID-19?

Written by Claire Nave
Illustrated by Akshaya Biju

Throughout the coronavirus disease 2019 (COVID-19) pandemic, we were all wondering when a vaccine will be made available. The timelines put forth vary wildly — in late 2020, some politicians claimed a vaccine would be available to everyone within the year, while many doctors and public health officials estimated it would take until 2021 or 2022. Vaccine development consists of lengthy stages and usually takes 10 to 15 years, but the coronavirus disease has spurred a massive effort to speed up the process. Lockdown measures in the United States (U.S.) have been sporadic and insufficient. With cases rising quickly, a vaccine might be the only way to end this pandemic. So why does vaccine development normally take so long, and how is it being sped up for COVID-19?

> Vaccines rely on the immune system to recognize pathogens it has seen before and target them with precision.

Like all vaccines, a COVID-19 vaccine would protect the recipient from contracting the disease. Diseases are caused by pathogens, or foreign molecules like viruses and bacteria, getting into the body and causing damage. Pathogens get into our bodies every day, but normally we can fight them. Our immune system, composed of a network of cells and signaling molecules, identifies pathogen molecules and mounts a defense to prevent them from causing harm. If a virus or bacteria gets into the body in large enough quantities or is especially damaging to our cells, it might cause symptoms despite the immune system's efforts to fight it.

Vaccines rely on the immune system to recognize pathogens it has seen before and target them with precision. When the immune system encounters a new virus or bacteria, it produces molecules called antibodies. Antibodies recognize specific pathogens and stimulate the immune system to respond if that pathogen is detected again. Once a pathogen is defeated, its antibodies still circulate in the body. That is the premise behind vaccines: they are designed to stimulate the immune system enough that it develops antibodies to recognize the pathogen in the future, but not enough to actually cause symptoms.

Vaccines can be game-changers in protecting people from disease, so what does it take to create them? The first step is the exploratory stage, which normally takes two to four years. This involves research labs identifying molecules that might make functional vaccines. Researchers must study how the virus or bacteria works because the vaccine must resemble them closely enough to produce an immune response but not so much that it actually causes the disease. Another consideration is that as viruses and bacteria spread throughout a population, they sometimes mutate into slightly different forms. Vaccines work best when they mimic a part of the pathogen that doesn't mutate as much, so they are effective on a range of different forms.

Once researchers have identified a vaccine, they begin extensive testing. First, the selected molecule is tested on cells and animals for around one to two years. Then it undergoes a series of clinical trials in humans. The Phase I clinical trial involves 20 to 80 participants, Phase II involves hundreds, and Phase III involves thousands to tens of thousands of participants. If they all demonstrate that the vaccine is safe and effective, it may be submitted to the Food and Drug Administration for approval.

A common refrain in coronavirus news is that even if a vaccine is approved, it will take weeks or months for it to be widely available. This is because in the typical vaccine development process, creating the infrastructure and carrying out all the steps to mass-produce a vaccine under regulatory oversight can take years. Safety standards for vaccines tend to be particularly high because they are designed for use by everyone, including children and the elderly. Therefore, extensive planning and documentation are required for every step of the manufacturing process – to the point where errors can take months or years to correct.

> Safety standards for vaccines tend to be particularly high because they are designed for use by everyone, including children and the elderly.

The vaccine development process is lengthy and complex, but it is moving at an unprecedentedly rapid pace for COVID-19. The novel coronavirus disease appeared in December 2019, the first vaccine began human clinical trials in March 2020, and 52 vaccines were in clinical trials by early November.

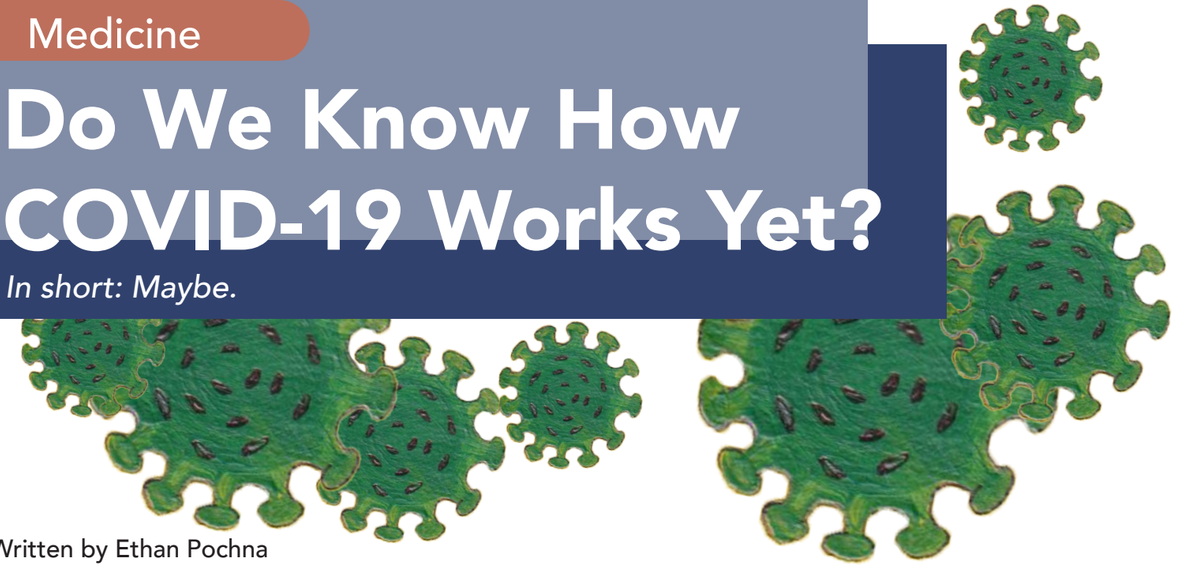
A key factor in speeding up vaccine development is the advances in basic science in recent years. For example, new genetic sequencing technology allowed COVID-19's genetic sequence to be published on January 11, 2020, which is extremely rapid. This gave researchers valuable information about the virus molecules, making it easier for them to develop a vaccine.

Another major factor is the global collaboration between industry, government, and academia. Collaboration allows discussions of clinical trial designs, data sharing, and early standardization of vaccine testing methods. For vaccines that move on to clinical trials, distributing the work of conducting trials and analyzing data among various labs reduces the workload for each, allowing faster progress.

Despite the sped-up timeline, there are unique challenges in developing a COVID-19 vaccine. For example, researchers often look at whether a patient develops antibodies after vaccination to measure whether they are immune to the disease. However, there is evidence that patients can have antibodies to COVID-19 but still not be immune, making it more complicated for researchers to test whether a vaccine is effective. Additionally, the lack of universal testing means that in clinical trials, researchers may not be able to tell whether COVID-19 symptoms developed by participants are due to the vaccine or from contracting the virus elsewhere. We can be cautiously optimistic about the rapid development of a vaccine – but in the meantime, there is no replacement for wearing masks, handwashing, and social distancing, for as long as we need to do so. • • •

Do We Know How COVID-19 Works Yet?

In short: Maybe.



Written by Ethan Pochna
Illustrated by Hannah Menosky

On December 31, 2019, health officials in Wuhan, China reported that a cluster of pneumonia had spread across the region. A day later, the World Health Organization (WHO) started to assess the incident. Then, on January 5, 2020, the WHO released a statement that is chilling to read in retrospect, wherein they asserted, "there is limited information to determine the overall risk of this reported cluster of pneumonia of unknown etiology … The symptoms reported among the patients are common to several respiratory diseases." We soon learned the etiology (cause of the disease), which attributed the outbreak to a novel coronavirus. We have also come to understand the risk, although that process has been long and far more painful. Though we have given the disease a name – the coronavirus disease 2019 (COVID-19) – we are still struggling to explain its effect on the body.

At the start of the outbreak, as the WHO's report indicates, we took COVID-19 to be a respiratory disease. Many, in fact, probably still do, and the attribution is hardly unfounded. COVID-19 most explicitly manifests as a breathing problem. When scientists first began looking for answers, they started at the lungs, and that is exactly where they found the novel coronavirus behind the outbreak. In fact, its genome, genetic material, was so similar to the virus behind severe acute respiratory syndrome (SARS) that scientists named the new coronavirus SARS-CoV-2. The disease's most frequent impact was quickly identified as COVID-19 pneumonia, wherein alveoli (the tiny networks of air sacs and blood vessels that put oxygen into our blood) leak fluid into lung tissue, and an overzealous immune response exacerbates the damage. In severe cases, this progresses into a type of lung failure called acute respiratory distress syndrome (ARDS), which involves an eruption of severe inflammation across the lungs that destroys the interior structure of alveoli, preventing our bodies from using the oxygen that we breathe in. The central role that immune responses play in the severity of COVID-19 cases raised some concerns about multi-system dysfunction. Given the intricate relationship between the immune system and all other organ systems, COVID-19 influence could be far more pervasive. However, these initial concerns were not enough to direct focus beyond the lungs, as intense inflammation is common enough among respiratory diseases and the early data lacked clarity.

Yet even as data came in that linked COVID-19 to other damage – mostly in the kidneys, liver, and heart – the trend still fit within our understanding of pulmonary (lung) infections. Reduced lung function means less oxygen makes it into the blood. The heart responds by circulating oxygen faster, i.e., raising blood pressure. Meanwhile, because the immune system is fighting infection, the blood is full of white blood cells that are massive compared to the blood's usual contents; this combination of mass and pressure can chip off pieces of plaque deposits that will tear vessel walls and careen toward vital organs. While these so-called plaque ruptures mostly impact the heart, the kidneys and liver are both vulnerable as secondary stops in blood's journey around the body. In other words, despite the data implicating the circulatory system, there were still ways to explain COVID-19 as a respiratory disease.

The number of these explanations rapidly shrunk by April 2020, when the compounds associated with immune, not respiratory, system malfunction had emerged as the most consistent trackers of COVID-19's severity. In May, the list of COVID-19's symptoms expanded to include fluctuating feeling in the toes, loss of taste, hyper-inflammation in children, sudden strokes in young adults, and "brain fog" in otherwise mild cases. Later that month, a study found that COVID-19's circulatory complications do not always involve plaque ruptures, and the medical community abandoned classifying COVID-19 as a respiratory disease. By June, scientists were rethinking the COVID-19 puzzle.

The symptoms provided some guidance, but the most important pieces in the puzzle of any disease are biomarkers, which are measurable substances in our bodies that track with disease severity and indicate the health of specific bodily processes. Glycated hemoglobin, for example, is indicative of blood-sugar level and is thus a biomarker of diabetes. In COVID-19 cases, the crucial biomarkers are high levels of plasma angiotensin-converting enzyme 2 (ACE2), D-dimer, Interleukin-6 (IL-6), and C-reactive protein (CRP). ACE2 is the protein that SARS-CoV-2 binds to in the body, D-dimer is a byproduct of the breakdown of clots, and IL-6 and CRP are both parts of the inflammation process. These puzzle pieces do not exactly scream "COVID-19," but the summer's investigation had to start somewhere, and the prime suspects to emerge were the immune system and the virus's receptor.

The immune system is one of the few bodily systems equipped with the ability to seek and destroy cells, so the consequences can be severe when it malfunctions. Such a malfunction was detected in the lungs early in the pandemic, so it could plausibly be the source of damage elsewhere in the body; however, that was not exactly an airtight hypothesis, and there was still the role of ACE2 to consider. In general, viruses use unique proteins embedded in cell membranes as their doorways into cells. Once they are in, they trick their host cell into producing copies of themselves and disperse those copies once enough have been made. Often, as with flu viruses, this dispersal happens by bursting the host cell wide open, creating carnage in infected tissue. ACE2 acts as SARS-CoV-2's doorway into cells, so if SARS-CoV-2 behaves like flu viruses, the role of ACE2 in the body could hold the answers.

ACE2 is a critical component of the renin-angiotensin-aldosterone system (RAAS), a signaling loop that regulates blood pressure. The RAAS begins in the kidneys. Low blood pressure initiates a signaling cascade in this system that ends with the production of ACE2's sister protein, ACE, converting Angio I into the hormone Angio II. Blood vessels interpret Angio II as a sign to constrict, and the kidneys interpret it as a sign to filter less water out of the blood, thereby raising blood pressure as more volume tries to move through a smaller space. The body's counterbalance to this process is the star of our show, ACE2, which inactivates Angio II, thus lowering blood pressure. ACE and ACE2 are both found in the membranes of endothelial cells, which form the inner lining of our blood vessels, and ACE2 specifically is mostly found in endothelial cells in the lungs, heart, liver, and kidneys.

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If SARS-CoV-2 kills the cells that express ACE2, this would certainly explain the damage to those organs. However, this perspective neglects several of COVID-19's other symptoms, meaning the medical community was still without a unifying theory. Then, in June 2020, two pivotal studies were published. One found that SARS-CoV-2, unlike influenza, does not kill the cells that it infects, opting instead to be spat out by the cell after copies are made. The second study found that COVID-19 corresponds with widespread thrombosis (clot formation) across our microvasculature (the system of tiny blood vessels in our tissue). While initially, these findings caused more confusion, a new theory that is gaining traction harnesses them to fit all of the pieces into place. The completed puzzle depicts COVID-19 as a disease of the endothelial cells.

The basic premise of the proposal is that all of COVID-19's damage emerges from the subtle disruption of endothelial cells' normal functionality, starting with plasma ACE2. Given the knowledge that SARS-CoV-2 does not implode its host cells, high plasma ACE2 suggests that the virus encourages its host to shed their ACE2 proteins while leaving ACE proteins intact. The consequence? Our old friend, Angio II, runs wild, resulting in increased blood pressure. While the body has some safeguards to prevent blood pressure from escalating too much, they are disabled in the elderly and patients with hypertension, leaving those populations especially vulnerable. And in otherwise healthy patients, Angio II's signals to constrict still exert disruptive stress on endothelial cells. Of course, that is only the beginning.

The real problems lie with IL-6, CRP, and D-dimer. D-dimer is perhaps the most bedeviling; it was the first biomarker discovered, and its levels elevate in situations ranging from pregnancy to sepsis, so its relevance to COVID-19 was initially unclear. However, the discovery of widespread blood clotting (microthrombosis) indicated a rather explicit relationship. Tiny clots spread with the disease through the endothelium, while D-dimer is generated as these clots break down. On the other end, IL-6 and CRP track disease severity with the same consistency as D-dimer, meaning that the tiny blood clots associated with COVID-19 is directly accompanied by inflammation; in a word, thromboinflammation. Despite the absurd name, thromboinflammation is a well-studied phenomenon caused by the dysregulation of endothelial cell function when they receive too many inflammatory signals. This makes endothelial cells produce clots to slow invaders and become incredibly permeable to maximize the number of white blood cells able to pass into local tissue. Even in normal conditions, the mix of white blood cells and clots creates severe blockages, and the over-accumulation of white blood cells generally damages both endothelium and surrounding tissue. When Angio II is on the loose constricting vessels, all of these effects are horribly exacerbated, causing a breakdown of the endothelium and damaging surrounding tissue wherever the disease spreads.

So, what does this mean for the body, and why should you care? First off, the endothelium exists wherever blood vessels exist, so RAAS dysregulation and thromboinflammation emerging from endothelial cells have the potential to affect just about every system in the body. This is especially true in areas with highly concentrated ACE2, like the lungs. Of course, just because a connection between two bodily processes might exist does not guarantee its existence, which is why the theory of COVID-19 as an endothelial cell disease is still just a theory. Nevertheless, it is the best understanding we have and is critical to informing the optimal targets for potential therapeutics. The more complicated the disease, the more complicated the treatment, and COVID-19 as an endothelial cell disease is very, very complicated. Unsurprisingly, COVID-19's most effective treatment thus far, remdesivir, does not even attempt to combat the disease's complicated effects on the body. Instead, it goes straight to the source by inhibiting SARS-CoV-2's ability to copy itself. Of course, the ultimate version of this approach would be a vaccine.

Just as important, though, is how this understanding benefits those of us without medical degrees. The specter of COVID-19 has long been daunting because of the fear accompanying its uncertainties. However, an unprecedented effort to uncover its mysteries has yielded crucial, if incomplete, answers, while simultaneously resolving so many of the questions lingering from less-studied diseases. The fact that nature could still stymie us shocked the world at the beginning of this pandemic, but we are quickly proving that we will not be stymied for long. • • •

Transgenerational Epigenetic Inheritance

What if Trauma and Stress Could Be Genetically Inherited?

Written by Bhavana Huliyar
Illustrated by Genevieve Kirk

The "nature versus nurture" debate spans a period of 150 years. While new evidence gently nudges the pendulum in one direction, it remains unclear whether genetics or environment plays a more critical role in the shaping of an individual. But what if the genes you inherit from your parents are not a tabula rasa, or a "blank slate?" What if, instead, they are molded by the experiences of your parents and grandparents? Your genes may carry a sort of memory of where they came from. The extent to which this affects future generations is what scientists today are trying to uncover, but they have only just scratched the surface.

The term "epigenetics" has been around since 1942, when it was coined by British embryologist C.H. Waddington to describe the interaction between genotypes and phenotypes. The study of epigenetics is now something quite different. It is an exploration of the biochemical markers on deoxyribonucleic acid (DNA) and the molecular mechanisms they cause in parents, which can influence gene expression in subsequent generations. Martha Henrique eloquently illustrated this idea in BBC Future: "it is not that fear is being passed down the generations — it is that fear of a scent in one generation leads to sensitivity to the same scent in the next."

The concept described by Henrique is called transgenerational epigenetic inheritance. In a study by neurobiologist Bianca J. Marlin at Columbia's Zuckerman Institute, it was shown that the physical brain structure and sensory experiences of mice offspring are altered by the stress experienced by their parents. Parent mice were exposed to an odor followed by an electric shock, which resulted in them developing a learned fear of the previously neutral odor. Marlin observed an increase in the number of olfactory cells, cells involved in smelling, inside the noses of these parent mice. Astonishingly, future offspring also exhibited a higher number of olfactory cells even though they had no previous exposure to the odor and shock sequence.

The influence of environmental changes on DNA has also been observed in humans. During the Dutch Hunger Winter at the end of World War II, a widespread famine ravaged the Netherlands. Subsequent Dutch generations were shown to have significantly higher metabolic ailments, including diabetes, high blood pressure, and even schizophrenia. It was a shock to see that children conceived after the famine had inherited biological characteristics of their ancestors as if the sex cells had a memory of that horrific trauma.

There is additional evidence for epigenetic inheritance in groups of individuals who have experienced immense trauma or stress. For example, sons of United States Civil War prisoners were shown to have an 11% higher mortality by their mid-40s, predominantly due to cerebral hemorrhage compared to sons of non-prisoners. On the flip side, daughters seemed to be immune to these effects, hinting at a possible sex-linked epigenetic inheritance. Another significant case involved survivors of the Holocaust and their children. This study looked at epigenetic markers linked to levels of cortisol, the hormone primarily involved in the stress response. Essentially, descendants had higher net cortisol levels and were, therefore, more susceptible to developing anxiety disorders.

It is evident that extremely traumatic life experiences like famine, war, or genocide can result in transgenerational epigenetic inheritance in some form. However, the extent to which biochemical markers and processes are inherited in situations of relatively moderate or lower stress is not clear. It is hard to study the effect of this in the human population outside of extreme cases because distinguishing between cultural and ecological effects becomes nearly impossible. Nevertheless, consider how children from less privileged backgrounds experience transgenerational trauma. For example, African Americans who experienced slavery have ancestors who continue to experience racial discrimination and injustice in their day-to-day lives. Were the slaves' stress responses genetically inherited by their children? Could this stress influence and amplify the impact of the stressors of the Black community?

> ... it was shown that the physical brain structure and sensory experiences of mice offspring are altered by the stress experienced by their parents.

While many of the effects of transgenerational epigenetic inheritance are still unknown, it introduces the question: can this be reversed? If so, how? The only way to know is by understanding how epigenetic markers are passed through generations. Alas, scientists have not yet figured that out completely. In fact, it seems like they have a ways to go since they keep fleshing out new kinds of 'pre-dispositions' that can be targeted by epigenetic markers.

We thought "nature" and "nurture," beginning at the time of an individual's birth, were the two sole influences on one's development, but the experiences of our ancestors seem to have an influence as well. Maybe we are not "blank slates" to begin with. Maybe our fates are predetermined. We do not yet fully understand the importance of epigenetics, but there is no doubt that its effects on the study of evolution, natural selection, and human disease will be far-reaching.

Green Energy in Industry

Put Green In, Get Green Out

Written by Kayri Craig
Illustrated by Adriana Baker

One of the more significant challenges of getting industries to use ecologically-friendly technologies is making them seem profitable. There has been a substantial amount of research on the impact that private research groups have on adopting sustainable technologies. However, private groups are not incentivized to research environmental technologies because the optimal path for them is to develop profitable innovations. On the other hand, little research has been conducted on the impact of public research organizations, though they may be the key to normalizing the usage of green technologies. Climate change is occurring at an astonishing rate, and the large corporations responsible for pollution need to become more ecologically thoughtful. Government legislation is crucial in motivating private industries to implement environmentally-friendly company policies.

Public research organizations, such as universities and government organizations, are government-funded and mandated. However, private organizations, like think tanks and research foundations, are led by corporations and capital optimization. Consequently, private research organizations tend to study new technologies, whereas public research organizations are left responsible for building upon existing ones to make them more dependable, economical, or environmental. Thus, the production of new environmental technologies is limited. Because the foundation of how research organizations choose their work is different for each type, what they work on and their outcomes will vary by legislation and the leading economic technologies.

A critical aspect of climate change is greenhouse gas emissions, which are created when fossil fuels are burned. Fossil fuels are typically cheaper than more sustainable alternatives, like solar and wind power. Therefore, private funds for research and technological development of sustainable alternatives are sparse. To address this problem, Mowery and colleagues suggest that the government tax fossil fuel sellers for the "social cost" of using their resources. This would hold companies accountable for externalizing fossil fuel's many detrimental effects.

Government laws and policies are more effective than government incentives in pushing industries to adopt sustainable technologies. A study analyzed a sample of environmentally friendly patents registered by public research organizations to quantify their effect on an industry's implementation of sustainable technology. The study concluded that technologies developed and researched by public research organizations proved to be fundamental in promoting a low-carbon society. The study identified several factors that characterize the most successful and ecologically-friendly technology. First, it is researched and patented by public organizations. Second, the patent has a high number of claims specifications as to which part of a technology is covered. Third, the patent is owned by several organizations that are based in the United States. Finally, that the patent has been renewed at least once. Following this template, public research organizations can increase the success, longevity, and implementation of their patented technology. Because public research organizations are more likely than private organizations to research and develop green technology, some amount of government regulation needs to exist for private organizations to receive the funds needed to research sustainable technologies.

A specific private industry that has promoted the shift to green energy is the hotel industry. A group of intercollegiate researchers studied how government regulations have different impacts depending on the technologies of the hotel industry. Green hotels follow an environmentally-friendly pattern that employs ecologically sound practices and sustainable development like water conservation, energy management, and waste management. The study concluded that government-imposed penalties were more effective than incentives in encouraging hotels to adopt sustainable practices. While government regulation is typically unwanted in the market, as time continues, initial regulatory policies will cause a decrease in government regulation. Government regulation will eventually decrease because instituting green practices will be more cost-efficient than government penalties. As a result, hotels would naturally turn to the more profitable green-practice. An example near and dear to Obies is the energy management at The Hotel at Oberlin. The rooms in the hotel are only supplied electricity when a keycard is placed into a slot near the door. This is an industrialized version of turning off or unplugging extension cords when you are not using them. Solutions such as these are becoming more crucial and practical, only causing higher costs in the short term from purchasing green technology but increasing profits in the long term.

> Technologies developed and researched by public research organizations are fundamental in moving towards a low-carbon society.

With climate change becoming a more pressing issue, finding environmentally-friendly technologies to replace harmful ones becomes the Earth's lifeline. The development and research of sustainable technologies can be moved in a positive direction with government regulation in industries, some of the highest contributors to pollution, and consequently climate change. Starting is the hardest part, but once industries begin to use environmentally friendly technologies, they will begin to see the long-term payout in profits and in a cleaner living environment.

Major Discovery on Mars, or Just a Hoax?

Rock County News Herald - Online press for Luverne, MN since 1991

Written by Sarah Barney
Illustrated by Nadeem Jones

Since the first Mars landing in 2028 by the Mars Pathfinder II mission, the National Aeronautics and Space Administration (NASA) has been collecting and retrieving rocks and other Martian samples for study on Earth. The data gathered from the Mars Pathfinder II mission proved scientists' long-standing theory that Mars once had the same geological systems Earth does now. Mars had a core, a mantle, and a crust, and therefore, plate tectonics. This implies that Earth a billion years from now will likely resemble Mars. From this discovery, scientists are more certain than ever that there was or may still be life on Mars.

The most recent Martian expedition launched from Houston, Texas in 2078. The mission was called Mars Sample Return (MSR) and, as the name suggests, it aimed to collect larger samples of regolith (soil) and rocks than ever retrieved before. MSR was headed by astrophysicist Shelby Borghosian, who has since retired.

"We are trying to remain realistic, but we are confident that our team will be successful," said Borghosian immediately following the launch.

The MSR team arrived back on Earth in March of this year carrying large amounts of regolith. In their analysis of these samples, geologist Jim Roach and his team of three graduate students from Georgetown University made a revolutionary discovery: there were trace amounts of coal within the regolith. Coal was once very common here on Earth, and was important in its function as a major energy source, but Martian coal is significant for a different reason. The discovery of coal on Mars is important because of the way coal is formed, a process in which remnants of plants and animals undergo a high amount of pressure over millions of years.

Finding coal on Mars proves there was life on Mars, making this discovery one of the most important in human history. Roach and his team are still heavily researching the coal sample.

"The amount of coal is very small, a microscopic amount. It is difficult to decipher when it was formed. Therefore, it is difficult to know how long ago this life existed," said Roach.

Despite this, Roach and his team are confident that a determination of the age of the coal sample is not far away.

"Finding this coal means there is likely more coal deep within Mars, like there once was on Earth," Roach continues. "I would like to begin work on another mission within the next year to continue this research, a mission that would prioritize the recovery of more coal samples."

There is no report of whether such a mission is being or will be planned.

Since its announcement, this groundbreaking discovery has been challenged by some as a political hoax from the President. The public has been wary of space discoveries ever since the moon landing of 1969 was proven false in 2063. The Cold War and the Russian-American race to space led the United States (U.S.) to lie about being the first country to walk on the moon, effectively ending what came to be known as the Space Race. Since Russia set foot on Mars in 2066, before the U.S., the competition between the countries has been rekindled. This has left Americans skeptical of space-related scientific advancement.

Additionally, more people have questioned the veracity of these discoveries since the United States elected our first openly atheist president, Rosanne Rayburn. She has previously argued that religion is the cause of many social issues, including racism, sexism, terrorism, and more.

Some believe this important discovery is just a ploy from the President to undermine religion in this country. Life on Mars would disprove Creationism, contradicting the Bible. If the discovery is a ruse, it would not be the first space-related government hoax, and it is not the first accusation either. Since President Rayburn's election, conspiracies accusing her of attempting to rid the country of religion have risen, including accusations that she forced the closure of various places of worship. However, the President has denied all such allegations.

Our community of Luverne is now lost in confusion and disbelief. Polly Blomquist, a local Sunday school teacher and owner of The Waffle Palace, says, "I just don't know what to think. It's hard to think straight when the government and the President are telling me one thing, but my head and heart are telling me something different. I just don't know who to believe." And she is not alone in this feeling. Local entertainer and comedian Mike Salvo, better known by his stage name Birdy, said, "This is a crazy time. The government has flat-out lied to us before. It's a fact! What makes people think they won't do it again?"

Yet not everyone is so disillusioned. Joe Corpuk, a biology teacher at Luverne High School, is among the excited.

"Just think about all the doors this opens! The scientific community should be absolutely delighted; this is a wonderful achievement."

For anyone confused by this momentous news, there will be a meeting at the United Lutheran Church at 5:00 p.m. this Wednesday, July 15th. It will be led by Pastor Joy Meyers. There will be an open conversation about the alleged conspiracy and how we can move forward. All are welcome.

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