THE SYNAPSE

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The Synapse

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Writers

Ruma Arabatti
Kileigh Ford
Nicole Franowicz
Norah Han
Anna Harrison
Emma Larson
Sophie Lyon
Golara Malaki
Aaron Morales Dolich
Elizabeth Toigo
Casey Troost
Barlow Wagner

Artists

Athina Apazidis
Doratea Crunk
Haley Giang
Emma Larson
Charlie Maddox
Roger Ort
Averly Sheltraw
Alex Tash
Isaac Wang
Logan Wallen

Layout Editors

Rebecca Fenselau
Victoria Fisher
Otto Kailing
Emma Keppler
Grace Kirk
Emma Larson
Kathy Li
Megan McLaughlin
Rebecca Shiloff
Nick Xu

Content Editors

Emery Angelo Bosela
Drew Dansby
Heather Do
Tori Fisher
Nicole Franowicz
Emma Keppler
Emma Larson
Yanni Sarrimanolis
Josh Spielman
Joy Zhong

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Becca Fenselau
Victoria Fisher
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Otto Kailing
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Yanni Sarrimanolis
Allison Schmitt
Josh Spielman
Emma Stillman
Evan Swanson

Photographer

Chris Schmuki

Cover Art

Athina Apazidiz

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Victoria Fisher (OC '21)

With the intention of capturing a broad audience, contributors at *The Synapse* characterize scientific progression of the past, present, and future. As the Editor-in-Chief, Victoria Fisher (OC '21) works alongside writers, editors, and artists to make this magazine possible. We always welcome new and consistent contributors and appreicate our loyal readers. Thank you for supporting *The Synapse*!

synapse@oberlin.edu
@thesynapsemagazine
@thesynapsemagazine
synapsemagazine.org

Featured Contributer

Miranda Marnik-Said (OC '20)

Miranda Marnik-Said became the Web Manager for *The Synapse* at the beginning of 2019. She is from Chicago, but plans on staying in Cleveland after graduating from Oberlin this December. With a creative writing major and with rhetoric and composition and French minors, Miranda also works as a Writing Associate in the Writing Center. Deeply interested in the sciences, she wanted to major in Neuroscience when she first came to Oberlin. Miranda loves *The Synapse* team because they are passionate about the sciences and dedicated to making the magazine the best that it can be. In her spare time she likes to write, read, and go to the gym. Her favorite characters in books or movies are spies and detectives like Sherlock Holmes because she enjoys discovering how they arrive at their answers.

Featured Contributer

Roger Ort (OC '21)

Originally from Connecticut, Roger Ort is a third-year student majoring in Biology and Environmental Studies at Oberlin College. He has illustrated The Synapse's cover for Issue 20, as many as ten articles including *Healthcare that Cares* (pg 6), *Anchored* (pg 26), and the Comics (pg 30) from this issue. Believing that bacteria may have untapped potential for generating energy, treating water, or combating pollution, Roger plans to study microbial ecology and limnology after graduating. Contributions to the Oberlin Comix Collective and work as an individually established comic artist occupy Roger outside of his studies. He appreciates *The Synapse* for being welcoming to new students and providing a platform for a scientific student voice. According to Roger, science and art are one and the same, both coming from an inherent place of desire to explore the unknown and communicate discovery with others.

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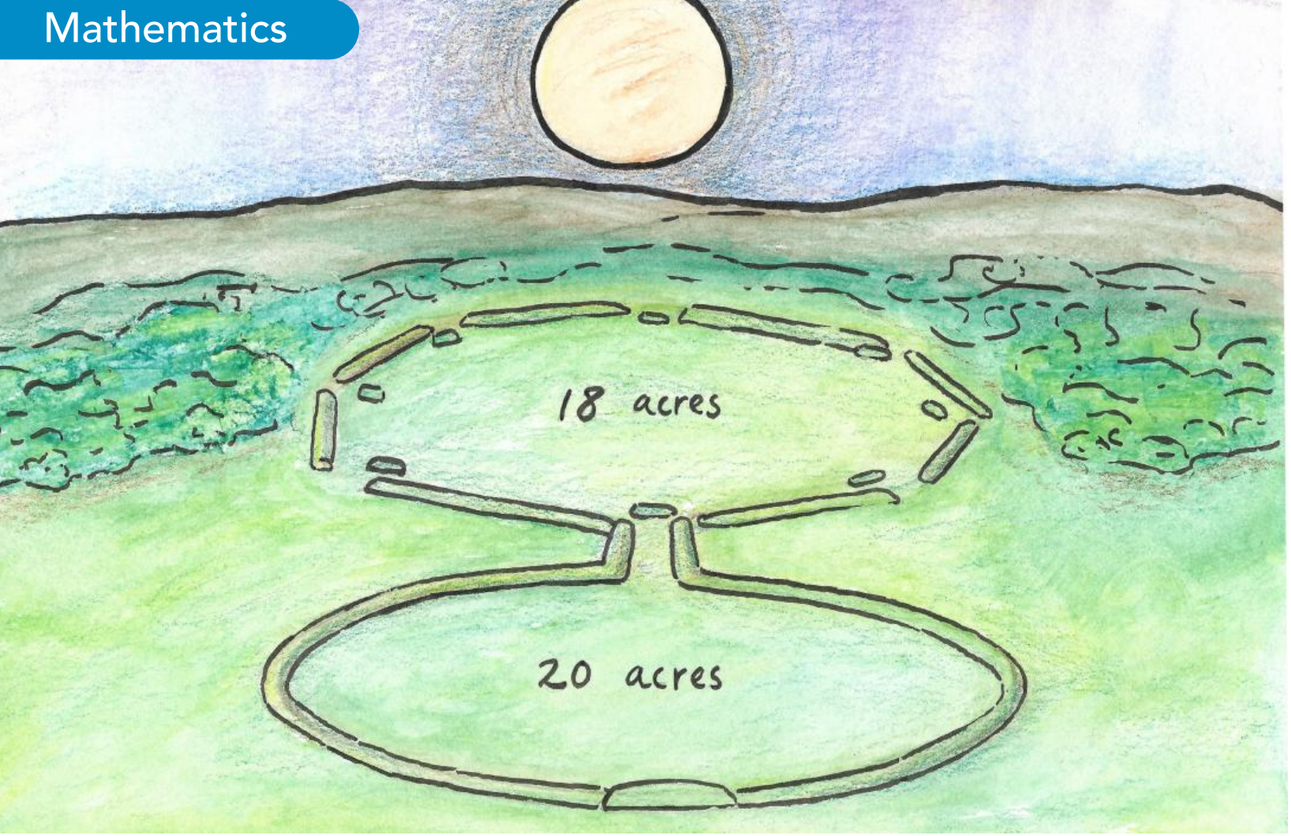

The Newark Earthworks

A Magnificent Piece of Archaeological History

Written by Kileigh Ford
Illustrated by Emma Larson

During the Middle Woodland Period, mound-building flourished across every region of Ohio. Although over 70 mounds, rounded and raised masses of earth, were created by indigenous tribes, few remain today. Without a use for these creations of raised earth, the 1800s saw the destruction of mounds across the state to make way for structures like the Erie Canal and railroad systems. The Newark Earthworks are no exception.

Located in Newark, Ohio, just two structures of the largest groups of mounds to exist in Ohio still stand today: the Great Circle and the Octagon. A work of mathematical calculation, these archaeological sites not only give us a glimpse into the history of the area, but evidence of people from across the continent visiting the site, indicates that they were one of the most important sites in prehistoric America.

The Newark Earthworks are a network of geometric shapes, embankments, and circles that were built by the Hopewell people between 100 BC and 500 AD. We owe our knowledge of what the mound system once looked like to the 19th-century surveyors, Squire and Davis. In their 1848 work, *Ancient Monuments of the Mississippi Valley*, Squire and Davis sketched what they saw of the geometric masterpieces. Their drawing consisted of a large octagon connected to a smaller circle, the great circle, an almost perfect square, smaller geometric enclosures, a dozen cone-shaped mounds, and parallel walls running between the structures. According to Dr. Frank Cowan, a consulting archaeologist at F. Cowan & Associates and research associate at the Cincinnati Museum Center, "these Earthworks were built on a scale that dwarfs many of the Old World's most famous sites." The Great Pyramid of Egypt fits within the square earthwork, 4 Roman Colosseums could squeeze into the Octagon, and Stonehenge could rest in the small circle connected to the octagon.

The Great Circle leads you into a stadium-like circle with a moat on the internal wall, thought to be a sign of religious use as it once held water. It spans 1,200 feet in diameter and encompasses 30 acres. The people of Licking County came together to save the site, recognizing its importance, and they ensure its preservation. Over the years, the Great Circle has housed county and state fairs, an amusement park, training camp for Civil War soldiers, a reunion for veterans, and a plot for agricultural growth. Today, the Great Circle is a public park owned by Ohio History Connection. The once barren soil is overgrown with grass, and trees have sprouted within its walls.

An archaeological excavation in 1992 found that the Circle was covered in a variety of different colored soils. The walls of the mound donned a dark brown clay while the internal surface was a bright yellowish-brown color. In the center of the Great Circle is Eagle Mound. Excavated in 1928 by the Ohio State Museum, remnants of a structure that would have been 100 feet long and 23 feet wide were found beneath the surface. A rectangular pattern of post molds found, according to Ohio History Connection, suggests prehistoric posts had been set in the ground. That is thought to have been a council house or used for ceremonies. Emerson Greenman, the archaeologist on the site, found a clay basin in the floor of the structure, thought to be an altar. It is thought that this structure was a special house where ceremonies were hosted by shamans.

The other remaining structure is the Octagon earthwork. This set of mounds consist of a 50-acre octagon connected to a circle smaller than the Great Circle. The Moundbuilders Country Club has had a lease on the land since 1910. The Octagon features Observatory Mound which is thought to have been the site of ancient astronomical practices. The viewpoint from Observatory Mound, looking straight down the parallel walls and to the smaller circle, aligns perfectly with the most northern rise of the moon which occurs every 18.6 years.

The people of Licking County came together to save the site, recognizing its importance, and [that] they ensured its preservation.

The first excavation of the Octagon occurred in 1836 by the Calliopean Society of the Granville Literary and Theological Institution, now Denison University. Digging into the southwest side of the mound, they found that limestone slabs had lined the surface of the mound. The second came when the Country Club decided to expand its maintenance building. Ohio History Connection came to survey the land by one of the entrances to the Octagon before they took action and found a six-foot-long pit filled with pebbles and limestone with a post-mold at the center. Using radiocarbon dating, the pit was found to be used between 250-390 AD. The post-mold may hint at the Hopewell people planning out the mounds before their actual construction.

The other components of these Earthworks have mostly been removed for industrial structures. The destruction of the burial mounds at the Newark Earthworks came when a rolling mill was built in their place. During this, an effigy pipe including an animal, a staple of the Hopewell culture, was unearthed. Called the Wray Figurine, the effigy pipe depicts a shaman pulling a bear head over his own. According to Bradley T. Lepper, the curator of archaeology at Ohio History Connection, "The Wray Figurine may represent a shaman in the act of transforming from a human to a bear spirit. The hand (or paw) on the side of the head suggests the shaman is lowering the mask to complete the transformation. In many American Indian cultures, the shaman would become an animal spirit in order to heal illnesses or find game animals for hunters." The figurine also depicts a head in the lap of the shaman, believed to be either an actual head or a symbolic head.

Findings from these excavations suggest that the mounds were a sacred site used for ceremonies. otherworldliness, and for solely special uses.

The vast size of these Earthworks keys us in to the importance of the site. Findings from these excavations suggest that the mounds were a sacred site used for ceremonies, otherworldliness, and for solely special uses. There is no evidence that anyone lived on the site, which only amplifies the importance and sacredness of the creations. A huge amount of copper from the Great Lakes, mica from Carolinas, seashells from the Gulf of Mexico, and volcanic glass from the Rocky Mountains have been found at the Newark Earthworks, suggesting an immense trade network of cultures all over the continent was based here or that the Earthworks were a pilgrimage destination for American Indians.

Through excavations we have seen glimpses of the lives that witnessed these mounds, findings of art and their architecture clue us into the lives of the Hopewell people and activity in early Ohio history. These mounds bring together a sense of community. Entering both sites instantly makes you feel like you are a part of something bigger than just yourself. Only further excavations can give us more pieces to the story of the Hopewell people and find out what has rested under our feet for the last 1,500 years. • • •

Healthcare that Cares

Price Transparency Arming Patients with Agency

Written by Golara Malaki
Illustrated by Roger Ort

How is it possible that the United States, which has the highest healthcare spending (per capita) in the developed world, is the harborer of a healthcare institution that simultaneously supplies the best care in the world yet systematically disenfranchises the majority of the American population? Well, it is a consequence of the "agency problem."

The "agency problem" — also referred to as the "principal-agent problem" — is the conflict of interests that may arise when a party (agent) is given the resources of another party (principle) to serve a third party. The management controls the firm directly since the ownership of a corporation is dispersed among a multitude of stockholders. Naturally, whether the management of a corporation is meeting the financial management goal of maximizing the current stock value is tied to the shareholder's wealth. So if management (the agent) isn't taking the necessary risk to achieve this goal or is diverting corporate resources to expenditures that don't benefit stockholders (the principle), then the shareholders' wealth is ultimately affected by the agency problem (Ross et al., 2018). Incentives, such as allowing management to have stock at a discounted rate, are methods of ensuring that the shareholder's wealth increases. Phenomena, such as proxy fights (shareholders using proxy votes to change management), are, in a sense, to ensure the agent (the serving party) is willing to take risks in hopes of increasing the value of the corporation's stocks.

This agency problem directly influences how healthcare insurance negotiates prices with hospitals in the patient's stead. When the patient pays health insurance premiums, the expectations are that the consumer is paying the healthcare insurance to negotiate down the cost of medical procedures and to cover part of these medical expenses. The intention of the Affordable Care Act (ACA) was to increase access to affordable health insurance and lower the cost of healthcare, in general, according to the U.S. Centers for Medicare & Medicaid Services. The ACA attempts to protect the principle's interests by coercively incentivizing insurance companies to use at least 80 percent of earnings from premiums for medical care. Still, insurance companies further illustrate the agency problem by accepting atrociously high fees for procedures that might be routine.. Before the ACA, these insurance companies were incentivized to lower service prices, since that meant the company could take in a more massive sum as revenue from the remaining premium. Though, with the enactment of the ACA, keeping the prices of medical services high was rewarded, because higher service prices mean that the company can justify charging higher premiums. Since the ACA allowed the insurance companies to make, at most, a 20 percent cut from the premium, the insurances would prefer to make 20 percent of a higher premium than from a premium that is low due to services being reasonably priced.

This lack of negotiations caused by insurances accepting institutional overpricing of services harms the patient three-fold. First, the healthcare insurances are not servicing the patient to their fullest capacity, simultaneously increasing the resources they demand of their clients by increasing the cost of premiums. Second, since the co-pay percentage is not significantly altered, patients are responsible for an enormous out-of-pocket expense. Third, as healthcare premiums rise, firms — especially small businesses — become more reluctant to cover their employees. As the premiums increase, so does the sum of money that the patient contributes directly to the medical service.

During the summer of 2019, there was another federal attempt to reduce the agency problem through an executive order that would significantly increase transparency for the pricing of medical services. This executive order would decrease the misuse of patient resources, as consumers would be better aware of their healthcare insurance acted in their best interest. This would incentivize healthcare insurances to serve their customers to their best ability because, otherwise, patients would seek out another agent to serve their healthcare insurance needs. Though this doesn't solve the issue of mispricing in the medical section, the executive order is a significant leap towards increasing accessibility and affordability.

Ultimately, the healthcare injustices, which are manifested in the overpricing of medical services, are rooted in the agency problem. In which, the consumer is unable to demand fair pricing from their insurance due to the inaccesibility of information regarding fair pricing. By enforcing price transparency, the medical sector's agency problem can finally be addressed. Healthcare insurance either has to negotiate for fair pricing of their client's service or risk losing a customer to competing providers that can meet the patient's expected cost of medical services. • • •

> "...insurance companies further illustrate the agency problem by accepting atrociously high fees for procedures that might be routine..."

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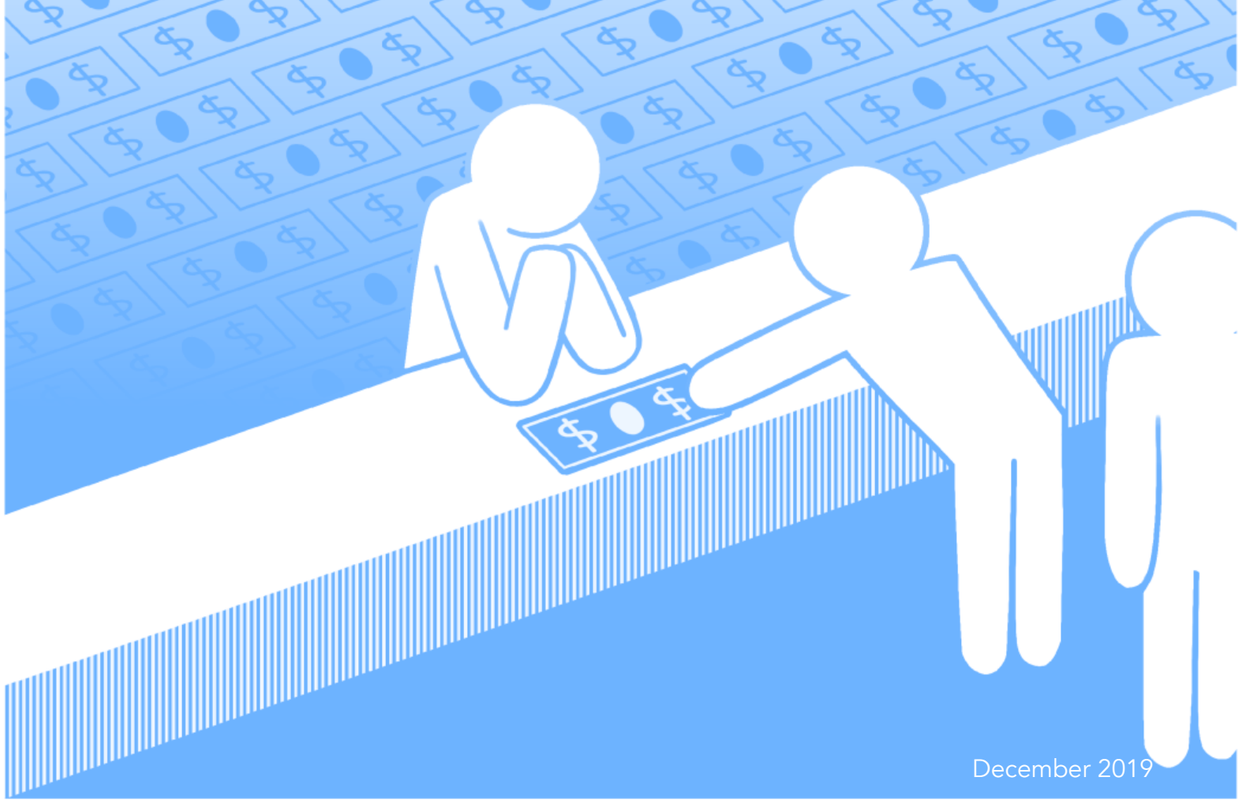


One Edit Closer to a Cure for HIV

CRISPR and CCR5 mutants

Written by Nicole Franowicz
Illustrated by Charlie Maddox

One of the most notable incurable diseases of the past century is Acquired Immunodeficiency Syndrome (AIDS). However, in the past five years, there have been some notable advances in treatment for HIV-AIDS. In September 2019, Chinese scientists demonstrated the use of clustered regularly-interspaced short palindromic repeats (CRISPR)-edited donor stem cells to treat an HIV-positive man with leukemia for approximately nineteen months without serious side effects, though the number of edited cells was not enough to cure the man's HIV. While similar experiments were carried out in 2007 and 2014, this study demonstrates more clearly how gene-editing can play an important and successful role in treating a seemingly incurable disease like HIV.

HIV has a shorter history than most other viruses, such as tuberculosis, polio, and influenza, whose histories date back centuries. Researchers first discovered the virus in the blood of a man from the Democratic Republic of the Congo in the early 1900s and believe the virus was spread from chimpanzees to humans sometime before 1931 from hunting encounters. HIV was first discovered in the United States Midwest in 1968. It is not clear how the virus got to the U.S. because the first infected man had no history with unsanitary blood transfusions or unprotected sexual activities. When the epidemic began in the 1980s, HIV was heavily stigmatized through its association with gay men; the CDC even called it gay-related immunodeficiency syndrome (GRIDS). People falsely believed that only men who have sex with other men could contract HIV.

During the past four decades, HIV expertise has increased throughout the world, with treatments more widely available. Doctors are now able to treat HIV more effectively than ever before. The virus' life cycle is exhaustively documented. Medications, like pre-exposure prophylaxis (PrEP), a preventative contraction process; antiretroviral drugs, like Combivir; and over twenty other FDA approved drugs, are making the virus more treatable, and mortality rates are down 80% since 1995.

> Antiretroviral drugs are becoming less invasive, from an injection, to a handful of pills, to a single pill.

The goal of HIV research today is to create new ways to kill the virus in the long term. Antiretroviral drugs are becoming less invasive, from an injection, to a handful of pills, to a single pill. Researchers are working on vaccines to prevent the spread of the virus. Meanwhile, HIV-positive individuals now experience a better quality of life than in any other decade, with viral loads of HIV infected cells nearing zero in those with high compliance to medication. However, scientists have still not found a cure. So, how are they going about finding one?

The first clue may lie within our genes. In 2007, a man in Berlin was the first person to be cured of HIV. Timothy Ray Brown underwent a bone marrow transplant to treat his leukemia. The bone marrow contained a version of the CCR5 gene that encodes immunity to HIV and is what caused Brown to become HIV free. While only about 1% of those with European descent have this mutation of their CCR5 gene, it is virtually nonexistent in all other ethnic groups, so it is difficult to find donors with this curable mutation. In March of 2019, another person underwent a similar procedure to Brown and appears to have no trace of the virus. Knowing that mutated CCR5 has the potential for a cure, researchers Xu et al. decided to use CRISPR, the new leading gene-editing technology, to create these CCR5 mutants from donor stem cells themselves. The subject was a 27-year-old HIV-positive Chinese man with leukemia who received a bone marrow transplant as Brown had in 2007. Researchers described the process as being very tough, and eventually, they were able to edit only 17.8% of the donor's stem cells. Their study, published in September of 2019 in the New England Journal of Medicine, has the potential to make a cure more accessible because of its use of donor stem cells.

> The researchers found that after 19 months, the CRISPR-edited stem cells did persist, although they comprised only 5–8% of the recipient's total stem cells.

The researchers found that after 19 months, the CRISPR-edited stem cells did persist, although they comprised only 5–8% of the recipient's total stem cells. This means that a little over one-half of the edited cells died in the man's body after they were transplanted. And although the man's leukemia is in remission, he is still infected with HIV. This result is clearly not the ultimate goal, but the researchers believe it is an important first step in treating HIV using CRISPR gene-editing technology. Greater therapeutic benefits in future trials may come when CRISPR-edited cells make at least 5-8% of the recipient's total stem cells moving forward.

CRISPR is still a new technology with massive unexplored potential. Every research study comes closer to unlocking the solution to killing HIV. If researchers keep putting their time and effort into studies like Xu and their colleagues, HIV-positive individuals living today could see a cure in their lifetime. • • •

Outdoor RX: Nature as Therapy

Why Spending Time Outdoors Could be Your Next Prescription

Written by Anna Harrison
Illustrated by Isaac Wang

New research is shedding light on the health benefits of being outdoors. From boosting one's mood and improving eyesight to shortening post-surgical recovery, there are more reasons than ever to go outside. This article will investigate just what these health benefits are and the physiological changes that may cause them.

The average American spends almost 90% of their life indoors. Spending so much time indoors can contribute to insomnia, anxiety, and depression. Exposure to natural "sun-strength" light helps your body establish circadian rhythms, according to Kenneth Wright, director of the Sleep Lab at the University of Colorado Boulder. In the absence of these natural cues, sleep and waking patterns can be disrupted, impairing your ability to fall asleep or wake up in the morning.

Sunlight isn't the only aspect of this "nature therapy." Even on those dreary Ohio days spending time outside improves your wellbeing. Several studies from Wright's lab showed that spending time in green natural environments boosts your mental and physical energy by nearly 40%. Fortunately for students at Denison and Oberlin, "green nature" provides more significant health benefits than any other type of nature (beaches, desserts, etc.).

While spending more time outside is optimal, just 20 minutes a day has shown to enhance vitality, as long as you leave your phone behind. If this isn't possible, getting plants for your dorm room or having pictures of nature also helps with relaxation, according to Richard Ryan, a professor of psychology at the University of Rochester.

So, it's clear that spending more time outdoors is good for our health; now the question is: Why?

Positive health outcomes are partially explained by the reduction of psychological stress pathways that are associated with diseases. Stress is physiologically linked to numerous diseases, including obesity and diabetes.

A group at the Center for Environment, Health, and Field Sciences at Chiba University in Japan summarized the benefits of "nature therapy" in regards to activity in the central nervous autonomic nervous, endocrine, and immune systems. They found a reduction in cortisol levels, heart rate variability, blood pressure, and heart rate for those receiving nature therapy. Outdoor therapy also has long term effects in increasing natural killer cell activity in individuals with weakened immune systems. Natural killer cells are an essential component of the innate immune system, fighting off pathogens we encounter on a daily basis and killing cancer cells.

Almost everyone can attest to a greater sense of relaxation, heightened focus, and a clearer mind after spending time in nature, even if it's not sunny and green. The lab at Chiba University observed these positive health changes in indoor studies with fragrant plants, suggesting there is also an olfactory component to nature therapy.

Aside from physiological benefits, researchers at the Medical College of Wisconsin have shown a direct relationship between time spent outdoors, more active lifestyles, and lower risk for chronic diseases such as cancer, cardiovascular diseases, and metabolic conditions. With chronic, non-communicable disease accounting for over 60% of overall global mortality (and growing), we should all take precautions to lower our risk.

These benefits span all ages: children show decreased levels of depression and anxiety, adults exhibit lower levels of chronic disease, and the elderly demonstrate improved cognitive function, emotional states, and physical ability.

In light of these discoveries, promoting time spent outdoors is a vital initiative in public health, regardless of if the time is spent increasing one's physical activity. This initiative could circumnavigate the challenge of promoting increased physical activity, acting as a less intimidating step towards increasing physical activity. Plus, researchers at the University of Essex have demonstrated that outdoor physical activity may have greater benefits than indoor.

Research on "nature therapy" has fueled promising public health initiatives, including programs like "Outdoors Rx," a collaboration between the Appalachian Mountain Club and the Massachusetts General Hospital for Children. Together these organizations pair exercise prescriptions with guided outdoor programs to increase physical activity among children who come to health centers serving low-income families. The program has shown favorable results as well as feasibility, thus they increased the size of the program to include more families.They found 78.3% of providers thought the program was a useful counseling tool. Further, the majority attested that Outdoors Rx increased the rate of physical activity counseling among patients. In fact, the pediatricians in this study prescribed outdoor therapy to about half of the patients they saw in a month. Implementing Outdoor Rx nationwide has the potential to improve numerous public health concerns in a feasible way!

They found a reduction in cortisol levels, heart rate variability, blood pressure, and heart rate for those receiving nature therapy.

So, next time you are feeling down in the dumps, ask yourself: how many minutes a day you've spent outside in the past week? A simple walk around the park could have significant and lasting health benefits.

Oh, Rats

Rodent Models in Human Neurological Disease Research

Written by Elizabeth Toigo
Illustrated by Doratea Crunk

Although rodents have been used in neurological research for years, new discoveries make it clear that we must rethink our use of rodents as models. Are rodents truly the best organism in which to study human diseases? Do the disadvantages of rodent models outweigh the potential advantages? Does the quantity of information gathered from rodent models justify their utilization? The conversation about rodent model use in neurological human disease research has been proven to be complex, with few known answers. However, it is clear that many have begun questioning such models, while proposing alternative means for neurological disease research.

One such model in question is the 5xFAD mouse, used to study Alzheimer's Disease. In 2016, Iaccarino and colleagues used such a model to examine how gamma radiation affects the activity of neurons affected by Alzheimer's. Although Iaccarino did use a mouse model to discover the potential role of gamma radiation in the neuropathology of this disease, the model was not flawless. We must ask, who created this mouse model? And how good of an Alzheimer's model is a mouse truly? Are our brains really being compared to that of a mouse?

On one hand, such a rodent model has a wide range of advantages that seems to justify its use in studying neurological diseases. For instance, mice are simple to breed and maintain, so that they are a convenient animal for neurological disease research. Researchers also have easy access to the genomic sequence of such mice, which allows experimenters to have a large selection of genes to manipulate to investigate their research question. Rodent models also have phenotypes that are observable shortly after manipulation, so differences in the affected mice compared to the control mice can efficiently be examined. Genetic engineering has lead to a diverse range of mouse models, and there has been a significant increase in studies that researches are capable of conducting. This is yet another advantage to rodent models. These advantages make it is easy to understand why researchers of human neurological disease widely utilize these rodent models.

However, there are disadvantages to rodent models human neurological disease research as well. Convenience does not completely outweigh these flaws in rodent models. For one thing, we must acknowledge that rodent models will never be perfect representations of human neurological diseases. These diseases are extremely complex. For instance, the diagnosis of Alzheimer's in humans is only certain post-mortem. The phenomena associated with this disease such as amyloid plaques, tau tangles, cognitive deficits and behavioral alterations each are unique and complex entities, so that it involves a system that is still enigmatic. How can we be sure that the genetic makeup of mouse Alzheimer's models are close enough to the human genetic sequences that cause the disease when we aren't even sure which sequences in the human genome they are?

There are ways in which mice are less than ideal models of humans. For instance, the 5xFAD mice overproduce amyloidogenic peptides in order to develop amyloid plaques and mimic Alzheimer's patients.However, humans Alzheimer's is most likely due to decreased clearance, not increased production. Furthermore, it has been found that there is a large discrepancy between the amount of published positive results (nearly 50%) and what is normally expected (less than 25%) when using rodent models for studying neurologic disease. Aside from the limitations associated with rodent models, such as small studies, the only potential explanation is reporting bias in only publishing positive results. Is an imperfect model still beneficial in human neurological disorder research?

Because of the flaws associated with the 5xFAD mouse model, Neuner et al. sought to create an improved mouse model for neurological diseases, by adding genetic diversity. The researchers combined the 5xFAD mouse with a genetically diverse model in order to generate mice called AD-BXD that have potential human mutations, yet still differ across their genome. his leads to differences between the onset and severity of Alzheimer's symptoms between individual mice within samples, which more closely mimics the onset and severity of Alzheimer's in humans. The AB-BXD mice's increased genetic diversity leads to a more representational genetic, and molecular features of Alzheimer's disease. Consequently, this new mouse model provides us with a better approximation of Alzheimers in humans.

> it is critical that when using these models, the limitations are evaluated every time people make scientific breakthroughs.

The advantages, and also disadvantages, of the current rodent models for human diseases make it clear that rodent models are extremely valuable for further understanding human neurological processes and providing a stepping stone for complex future studies. Therefore, it is critical that when using these models, the limitations are evaluated every time people make scientific breakthroughs. Those evaluations will allow subsequent researchers to build more representative models. As the neuroscience community develops, it will become increasingly important to develop more representational models that mimic human neurological diseases. Luckily, new innovations such as AD-BXD mice in the Neuner lab are providing a path for future scientists to follow when producing new rodent models. • • •

A Synapse Series: History of Science

The History of Chemistry

Chemical Education in the United States

Written by Emma Larson

Illustrated by Alex Tash

Humans' first major external interaction with chemistry was probably playing with fire. Fire and subsequently chemistry define the separation of the ages from the Stone Age to the Iron Age. Early humans found naturally occuring bits of gold, silver, copper, and tin, and sought to refine them for their unique aesthetic and practical qualities. During the Bronze Age people were able to smelt tin, lead, and copper in order to make more effective tools, but the Iron Age finally saw successful production of iron. Concurrently with chemical or industrial technological developments, various civilizations developed theories about the core properties of substances in our world. Mayan, Chinese, Greek, and other philosophers believed that air, water, earth, and fire were primary elements. Still including these four primary elements, alchemy refers to the early philosophical discipline in which primary goals were to purify, transmutate and perfect substances, particularly metals. Just as multiple theories about elements existed around the world, so too did various iterations of alchemy for hundreds of years. Greek and Arab alchemists set the foundation that enabled early chemists to more exactingly explore purification of metals as well as glass production in the 1500s and 1600s. With the advent of the scientific method, European scientists shortly divorced chemistry from alchemy and took off running.

From the mid 17th century until the early 19th century, articulating basic chemical relationships, developing a chemical nomenclature, and exploring the periodic table occupied chemists around the world. Before the development of the periodic table, Robert Boyle, Joseph Priestley, and Antoine Lavoisier made some key scientific contributions. Earlier alchemists focused on the transmutation of metals, but Boyle was primarily interested in gases. He determined in large part the relationship between volume, pressure, and temperature of gases, now commonly referred to as Boyle's Law or PV=nRT. He also wrote the first chemistry textbook, "The Sceptical Chymist," in which he denounces alchemy. While Boyle examined gases' behavior, Priestley observed their composition and realized that air was made up of many distinct gases. This discovery was groundbreaking because up until this point people still argued that air was an indivisible element, harkening back to the four elements of earth, water, fire, and air. Boyle and Priestly began the divergence from alchemy, but it was Antoine Lavoisier who set the stage for modern chemistry and other disciplines by creating a system for meticulous measurements and the guidelines for naming compounds which are still used today. In turn, he gave chemists the means to make precise calculations and clearly communicate their research.

With Laviosier's invaluable naming and measuring systems in place, people in the 1800s witnessed a crusade to isolate all of the existing elements and determine the fundamental structure of atoms. John Dalton's more exacting definition of an atom started the 19th century scientists off strong in discussion of structure, but further strides in understanding atoms' components wouldn't be made until the very late 19th century and into the early 20th century. Isolation of individual elements was the more intensely investigated topic. By 1830, scientists recognized about 50 elements and started to notice patterns in their behavior. However, confusion in the chemistry community surrounding atomic weight, molecular weight, and equivalent weight prevented chemists from establishing the true relationships between the elements. With a better understanding of atomic weight through Avogadro's hypothesis, Dmitri Ivanovich Mendeleev tried ordering the elements by their atomic weights and valences, publishing the first recognized periodic table in 1869. His table predicted then undiscovered elements, boron, aluminum, and silicon. Within 15 years of his publication, these elements were discovered and matched Mendeleev's predictions, thereby confirming the validity of the table and its outlined relationships. Doubt about the table was completely erased after scientists successfully adapted it to accommodate a plethora of other elements. These key chemical discoveries were made possible in large part by new tools, especially hardy borosilicate glassware and spectroscopic techniques.

So...where are we now? The history of chemistry is a long one that has always been closely tied to the search for tools and materials; some believe that the golden age of chemistry is over while others believe that chemistry's practical applications are limitless. Automation, world-scale production, nanotechnology, and environmental protection seem to be especially promising ventures for the modern chemist. But how can chemistry students prepare themselves to solve these puzzles? With ever changing industrial and technological landscapes, it is difficult to reconcile chemistry's history and future with current educational practices. Controversy about what kind of practical training and theoretical knowledge undergraduate chemistry students should receive in order to prepare for industry or graduate education has always persisted but seems especially prevalent considering current educational expenses and obstacles. Nowadays the chemical industry demands employees who hold graduate-degrees such that many people view undergraduate programs as merely prerequisites for graduate school or as education for technicians. But why is chemical education in this state?

Unsurprisingly, education was a bit different in the 17th and 18th centuries than it is now. Many European universities were established in the 13th century, and had theological or humanistic origins which emphasized topics such as philosophy, medicine, logic, theology, law, mathematics, astronomy, and grammar. Because the educational model for these universities remained relatively stagnant and because scientific discoveries required adaptability (and sometimes made theological implications), education for the sciences diverged from that of the humanities. Chemistry became closely associated with medicine and pharmacy, so medical students were the first to receive an education including chemistry in early America. In the US, the first undergraduate chemistry course was taught in 1757 and the first chemistry chair was appointed at the College of Philadelphia in 1769.

Beginning in the 18th century, the German educational model which promoted academic freedom, seminars, and laboratories was so successful that many American and European chemists studied there throughout the 19th century. Public universities with less religious influence also arose in the US during this time, and secularization and competitive industrialization caused these institutions to prioritize the sciences, a phenomenon arguably still seen today. The United States became a strong proponent of the German educational model and research universities, while many other countries still relied on older European models. Secondary education was not standardized at this point such that chemistry was taught to high school students in varying degrees or wasn't taught at all in the 19th century. Even when chemistry was taught, it was mostly reserved for white male students. Though well established in schools, chemistry was viewed as a genteel discipline and not terribly practical until the industrial revolution took hold. As the industrialization process gained steam, chemistry students grew in numbers and the common perception of the discipline changed. Chemistry's close relationship to industry became crystal clear at the turn of the 20th century when a strong commercial demand for college educated chemists started to develop in both Europe and the United States. Mass education enabled America to industrialize, become competitive in the global economy, and let the disciplines of physics, chemistry and biology come into their own through the 19th and 20th centuries.

In the face of tension between academia and industry, a rapidly changing body of chemistry knowledge, and an outdated educational model, young scientists must cultivate strong communication skills and efficient learning abilities. Becoming a self-sufficient learner for life, understanding the most recent technologies and access to online resources can help to provide this foundation. However, this understanding and access is not pervasive. Educational institutions including both universities and secondary schools are slow to integrate new technologies due to limited access and resources. This lagging pace is frustrating with the simultaneous rise of vocationalism in universities. The responsibility of grasping and adopting new technologies currently lies with students as individuals, but chemistry students can also advocate for educational reform with comprehension of the discipline's past, present, and future in which chemistry and industry are joined. • • •

What's Actually Going on with the Bees?

I See the Slogan and Can't Help But Wonder…

What's Actually Going On with the Bees and Why Do They Need Our Help?

Written by Barlow Wagner
Illustrated by Averly Sheltraw

"Save the bees" has become the motto for a new generation of bee activists. The movement grew very quickly — especially with the support from millennials and young adults. The campaign has been sensationalized throughout the media, spreading across the United States at an impressive rate. However, it's important to understand that campaigns like these sometimes spread misinformation. It isn't necessarily on purpose; it just has to do with poor communication.

First off: the European honeybee, the bee that is all over "save the bee" news, isn't endangered. In fact, the worldwide European honeybee population has been in a steady incline for over a decade.

Second, people are mistaking colony collapse disorder (CCD) for overall population decline. They're not the same thing.

Lastly, the European honeybee is not the only species of bee in North America. Individuals seem to automatically associate honeybees with the "save the bees" movement. In reality, there are around 20,000 species of bees on this planet, and the European honeybee isn't the species of primary concern.

The hype around bees started in 2006 when a bunch of beekeepers reported a strange decline in 30-90% of their hives' honeybees. They were upset and jumped to the conclusion that pesticides were wiping out their bees. However, the affected colonies weren't demonstrating symptoms of pesticide poisoning. It's typical for hive populations poisoned by commercial pesticides to have large numbers of dead bees outside the hive. However this was not the reason for the bees disappearing in 2006. The bees simply disappeared.

According to the EPA, "[colonoy collapse disorder] occurs when the majority of worker bees in a colony disappear and leave behind a queen, plenty of food, and a few nurse bees to care for the remaining immature bees and the queen." The worker bees disappear from their hives almost overnight and never return. The triggers of CCD are still widely unknown and

The worldwide European honeybee population has been in a steady incline for over a decade.

scientists are currently in the process of understanding the root cause. CCD was initially thought to have been a major threat to the worldwide honeybee population, and beekeepers were rightfully concerned. However, there has been a steady decline in cases of CCD since 2006, and it's not a problem anymore.

In contrast, a species native to the Midwest, the rusty patched bumble bee, has been hit hard by the times. In much the same way that farmers during the Dust Bowl lost land to desertification, the rusty patched bumble bee has lost large swaths of habitat to urban development and the agriculture industry.

The rusty patched bumble bee has recently been added to the U.S. Fish and Wildlife Services' Endangered Species Directory, meaning that the species is in danger of becoming extinct. Other animals on this list include the giant panda, the orangutan, and the wood bison. Unfortunately, the "save the bees" movement has largely overlooked the rusty patched bumble bee. This is a problem — especially regionally. There are more species to be concerned about than our cherished European honey bee. Native bees, such as the rusty patched bumble bee, are major pollinators. The Xerces Society, an invertebrate conservation group, claims

The hype around bees started in 2006 when a bunch of beekeepers reported a strange decline in 30-90% of their hives' honeybees.

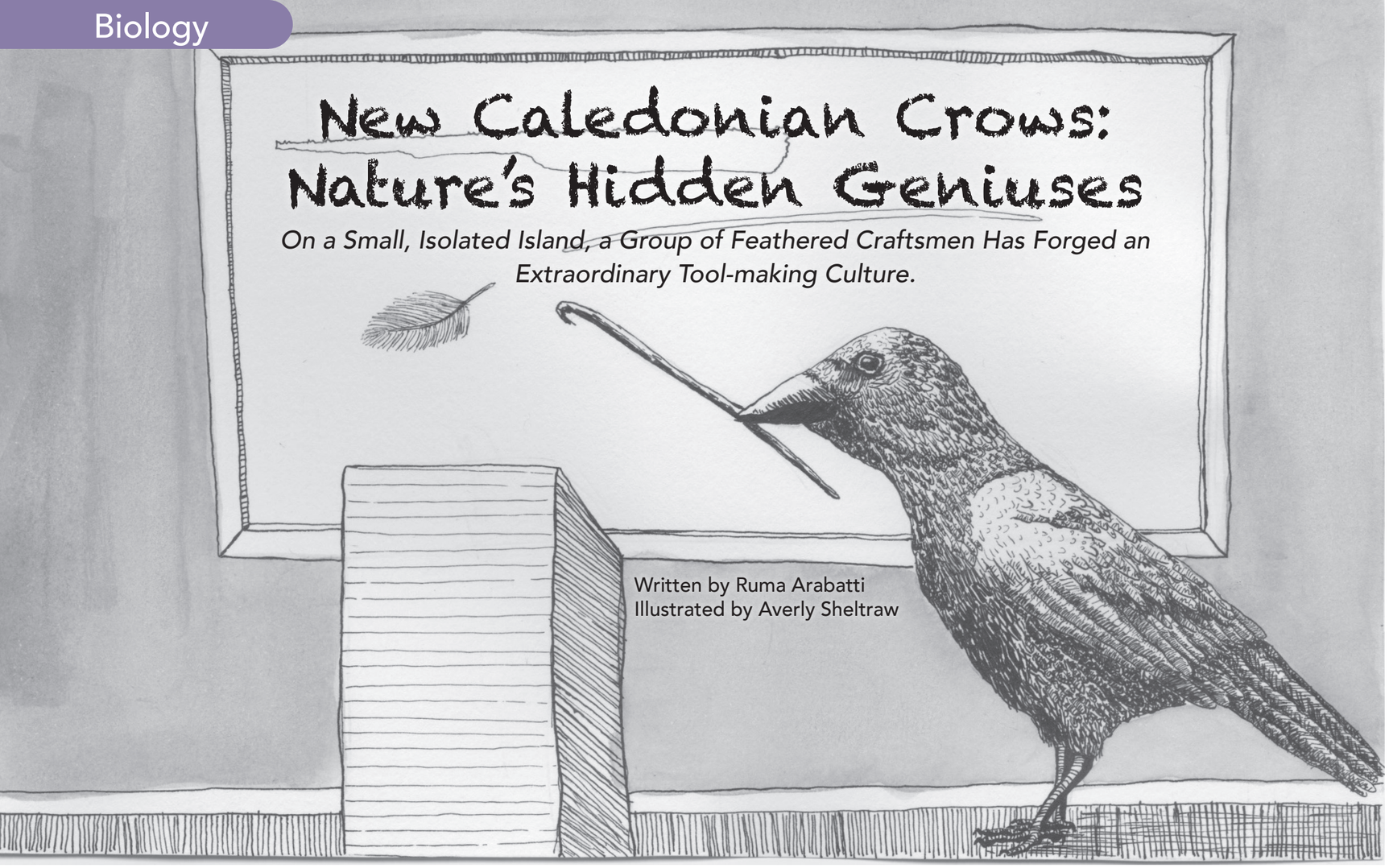
that the rusty patched bumble bee was once an excellent pollinator of wildflowers, cranberries, and other important crops, including plum, apple, alfalfa and onion seed. Because of their declining population, this is no longer the case. People interested in advancing and retaining our environment should understand the importance of pollinators in our world. If we continue to allow the bee population to decline, we will lose access to the crops we need to sustain our society. Without pollinators like bees, the world would be a totally different place — a place where a trip to the grocery store could put a pretty hefty dent in your wallet.

If the "save the bees" movement has done nothing else, it has certainly encouraged activism and highlighted the significance of population decline. People are now more concerned about bees than ever before. The public is finally starting to recognize the importance of bees for the human population as a whole, and no longer view them as things that fly around and sting people. Individuals are donating to research organizations and taking steps to better the ecological diversity of native bees in North America. It's a great step in the right direction.

If you're wondering what tangible steps you can take to help save the bees, you can easily start by planting native wildflowers. Packets of wildflower seeds can be bought online or at hardware stores like Lowes and Home Depot. Planting native plants is a super easy thing to do to help native bees. • • •

New Caledonian Crows: Nature's Hidden Geniuses

On a Small, Isolated Island, a Group of Feathered Craftsmen Has Forged an Extraordinary Tool-making Culture.



Written by Ruma Arabatti
Illustrated by Averly Sheltraw

With only a wire, tube, and her brain, a crow named Betty stunned the world. Nearly seventeen years ago, experimenters filmed a captive crow bending a wire into a hook and using it to fish out pieces of tasty pig heart at the bottom of the tube. Her intelligence seemed to be pulled out of fiction. Until very recently, birds were dismissed as dim-witted masters of flight lacking in the cognitive department. However, research in the last few decades has shown otherwise. The corvid family in particular, which includes jays, magpies, and crows, triumphs in intellectual skills, and Betty's species is a misfit even among them.

Betty is a New Caledonian crow--a corvid that resides on the French-owned archipelago located 750 miles east of Australia. James Cook, the British explorer who discovered New Caledonia in 1774, remarked that the island, with its mountains, streams, woods, and beaches, "might afford a place for romance." About 37 million years ago, the southeast Asian or Australasian ancestors of the modern New Caledonian crow arrived on its shores. As the crows settled in, they discovered some of the best food could be found in out of reach places, requiring more than just a beak and claw.

Before the 20th century, the ability to use tools was thought to be something only humans possessed. This changed in the 1960s when Jane Goodall observed chimpanzees using twigs to grab at termites and rocks to crush nuts. Since then, scientists have observed many other animals using tools, including elephants, gorillas, and dolphins. NC crows are the only species besides humans ever to make hooked tools, indicating a level of intelligence that might even rival primates.

What types of tools did these birds make? In a survey by Gavin Hunt of the University of Auckland, it was found that the crows had three types of tool designs. One is a twig curved at the working end, while another is fashioned from the barbed edges of a pandanus leaf. A more elaborate version of the latter included a stepped tool, a pandanus leaf tapered towards the working end.

Even their bodies bear marks of sustained tool use. Unlike other crows which have curved beaks, NC crows have long, straight beaks, like tongs for a steady grasp. Their eyes are also closer together than other crows', granting a greater overlap of vision. This allows them to get a better view of the bottom of a dark, narrow place, such as a log.

How can creatures weighing as much as a baseball be so evolutionarily advanced? One explanation lies just inside the crow's head. Although there is no perfectly accurate method of correlating brain mass with intelligence, there are a few indicators that imply causation. The encephalization quotient (EQ), the ratio of actual to mathematically predicted brain mass, predicts that an NC crow will have an EQ of around 3.0-4.0. Squirrels weigh the same as the crows but have an EQ of only 1.0-2.0. In order to understand why NC crows have such a large relative brain size, scientists look at the possible evolutionary pressures surrounding them. A review by Christan Rutz and James J.H. St. Clair of the University of Oxford found that NC crows have very few predators. Therefore they face little pressure to develop anti-predation mechanisms, such as vigilance and fear of the unknown, significantly reducing cognitive load. This leaves the birds with more time to explore and interact with their surroundings. THe lack of predators also explains why NC crows are weak fliers compared to their flight-ready ancestors. The lessened need for dependable aerodynamic facilities reduces the pressure to have a relatively lightweight brain. Reduced risk of predation also allows NC crows to spend more time with their parents, delay reproductive maturity, and live longer.

But what if these apparent "intelligent" behaviors are simply the result of genetic predisposition? Thousands of ants can cooperatively build intricate networks of tunnels underground. Is this not a sign of high intelligence, since it's a feat that not even humans could accomplish? With this in mind, a more precise definition of intelligence is required. Instead of basing intelligence purely on genetics, learned and applied knowledge needs to be taken into account as well. In several controlled trials, captive crows demonstrated tool use behaviors, just like Betty. This begs the question: are NC crows born with the innate skills to make complex tools?

Despite the crow's strong genetic predisposition, education is still an integral part of its learning. For the first few months, a young crow must undergo tutoring from its parents. They watch their parents skillfully craft tools, and later, the young crow's knowledge is put to the test. Most crows are not prodigies; it will take them at least six months before they're as adept as their parents.

Several mental processes allow NC crows to make and use tools in novel ways. After a crow has gathered the necessary materials, its mind lights up. Like an architect sketching a new bridge, the crow will formulate a mental template of the tool it wants in its mind, and then set out to craft it. In an experiment performed by Alex Taylor of the University of Auckland, eight wild crows were trained to drop variously sized pieces of paper into a vending machine in exchange for a treat. Then, the crows were given large pieces of paper. Instead of dropping those larger pieces, they tore them up until they approximately fit the same size as the previous pieces. Since the crows didn't have a physical image of the tool to reference, they had to picture it themselves.

A well-known children's fable tells of a clever crow that drops stones into a pitcher full of water so it could quench its thirst. This requires causal understanding, the ability to predict what will occur from a root cause. To humans, causal reasoning is a crucial ability that has lent us the cognitive power we have today. Human children usually acquire causal reasoning a year after they learn language skills. NC crows may have it too, which would partially explain why they are so adept with tools.

In another experiment by Taylor, eight NC crows were given stick tools in order to extract meat from a box. The crows had to probe for food while avoiding a "trap", a hole in front of the food. If the crows were able to reason causally, then they should be able to think as follows: "If I attempt to extract the food over the hole, then it will fall." And further: "If the food falls, then I will go hungry." Taylor's team found that most of the crows demonstrated causal reasoning, thus ruling out the possibility of trial-and-error. This transformative discovery has shed light on the cognitive processes of NC crows' mind and could help explain their sophisticated tool use.

It seems impossible for a crow to make as intricate a tool as the stepped pandanus leaf, even with tutoring from its parents. It's like expecting a person from the Middle Ages to build a computer. Humans became so intellectually successful by transmitting knowledge and slowly refining that knowledge with increasing complexity. This process is known as cumulative cultural evolution, and it was thought to only occur in humans. It was only recently that evidence of culture was found in primates. In his geographical survey of New Caledonia, Hunt found distinct twists of the same tools, indicating the existence of socially transmitted information. NC crows are often seen in large groups or as a breeding pair, allowing for complex social structures. Experts speculate that the existence of complex social structures is a primary driving force behind sophisticated cognition. This is known as the social intelligence hypothesis.

Though there is still little known about the cognitive processes of New Caledonian crows, there are myriad possibilities for exciting discoveries. At the moment, we can only speculate about what is happening within their vibrant minds. • • •

Our Beef with the Environment

Emphasizing Humanity in Environmentalism

Written by Casey Troost
Illustrated by Haley Giang

It's 2019, and global researchers worry for the world's future; their concerns stem from predictions of an excessive increase in global demand for ruminant meat — meat from cows, sheep, and goats. The World Resources Institute, a nonprofit organization, published a report in July on the world's agricultural path to a "sustainable food future," predicting that the difficulty of feeding another 2.1 billion people by 2050 would be "substantially greater than commonly presented" in previous studies. The WRI published the full report, an expansion of a synthesis report they had published the previous December. Both reports framed their goals through three "gaps." Two gaps concerned food supply and land use and compared studies in 2010 with predictions for 2050. A third gap concerned greenhouse gases, and compared 2050's projected emissions of fifteen gigatons with a goal of four. The synthesis report explained that a "major driver" of these gaps was a predicted eighty-eight percent rise in global consumption of ruminant meat. The world's ability to protect its environment and food supply hinges on limiting this rise.

Explaining the forces behind this predicted increase, the WRI identified a trending diet change amongst modernizing countries. Diets are widely changing to be more "'Western,' [meaning] high in [...] meat, and dairy," which reflects a "large global rise in consumption of animal-based foods." While consumption increases, the WRI noted it was excessive to begin with. According to the report, "half the world's population already consumes 50 percent more protein than needed." In order to get on track for closing the gaps, the top fifth of global consumers would need to limit their consumption by forty percent. However, this reduction is attainable. The forecasted increase may not be a symptom of rising hunger. As Wilson Warren explains in an essay published on Zócalo, this increase could signify rising global wealth. Warren explains that Americans have historically valued meat as a symbol of prosperity and nutrition. As a meat-intensive western diet becomes more popular, so does meat's symbolism. Therefore, one of the keys to reducing ruminant meat consumption lies in challenging this perception.

Though ruminant meat consumption is too high all over the world, the US is especially responsible as a beef-loving developed country. In Medium Magazine, Jonathan Foley reported "we eat four times the global average." Though this statistic is already high, it's likely our excess is worse than how Foley portrays it. The global average may not be target-worthy, considering half the world eats too much protein. In addition, our overconsumption is further aggravated by a bad habit of wasting food. The full report stated that more than half of global food waste happens at the hands of developed countries, and that in North America, consumers are responsible for two thirds of it. To illustrate this point, the report estimated the average American family throws away fifteen hundred dollars' worth of food a year. As one of the world's worst consumers of ruminant meat, or beef, the US needs to cut down on its consumption, or at least its waste.

The environmental implications of US beef consumption go beyond its excess and wastage to include its production method. According to Foley, the majority of US beef comes through feedlots, which Pierre Gerber and other researchers describe as having "high impacts on water resources and air quality." Foley summarizes that feedlots pollute their surrounding areas with "manure runoff, water pollution, air pollution, and noxious odors." He adds that feedlots annually produce a hundred and thirty times more excrement than human feces in the US, and much of it goes directly into natural water. As these authors show, the US's over consumption and waste exacerbates the already high environmental impacts of feedlots. Most importantly though, this high pollution results from a choice, not a need. Gerber states that feedlots "respond to a demand for beef expressed by a food secure population," meaning a reduction poses no threat to the US's nutrition. It's possible many Americans already know reduction comes at no cost because consumption has already been declining. The WRI's full report noted that the US still held potential for further lowering its consumption as demand had already dropped by a third since the seventies. Still, we haven't reduced enough. If Americans continue to eat four times as much beef as the rest of the planet, is it rational to assume we'll realize this potential naturally?

A large reason that beef consumption continues to grow is that environmentalist arguments downplay how environmental problems are symptoms of global socioeconomic inequalities. The WRI's full report warned it neither accounted for the "socioeconomic factors" influencing food systems nor provided "remedies for tackling acute food shortages in the short term." In effect, the report acknowledged that food system changes would have negative impacts on poorer regions and therefore require systemic socioeconomic changes, yet still integrated these

> In order to effectively improve the US beef industry we must make our perspectives more inclusive, and change what we commonly understand as an environmental problem to a human one.

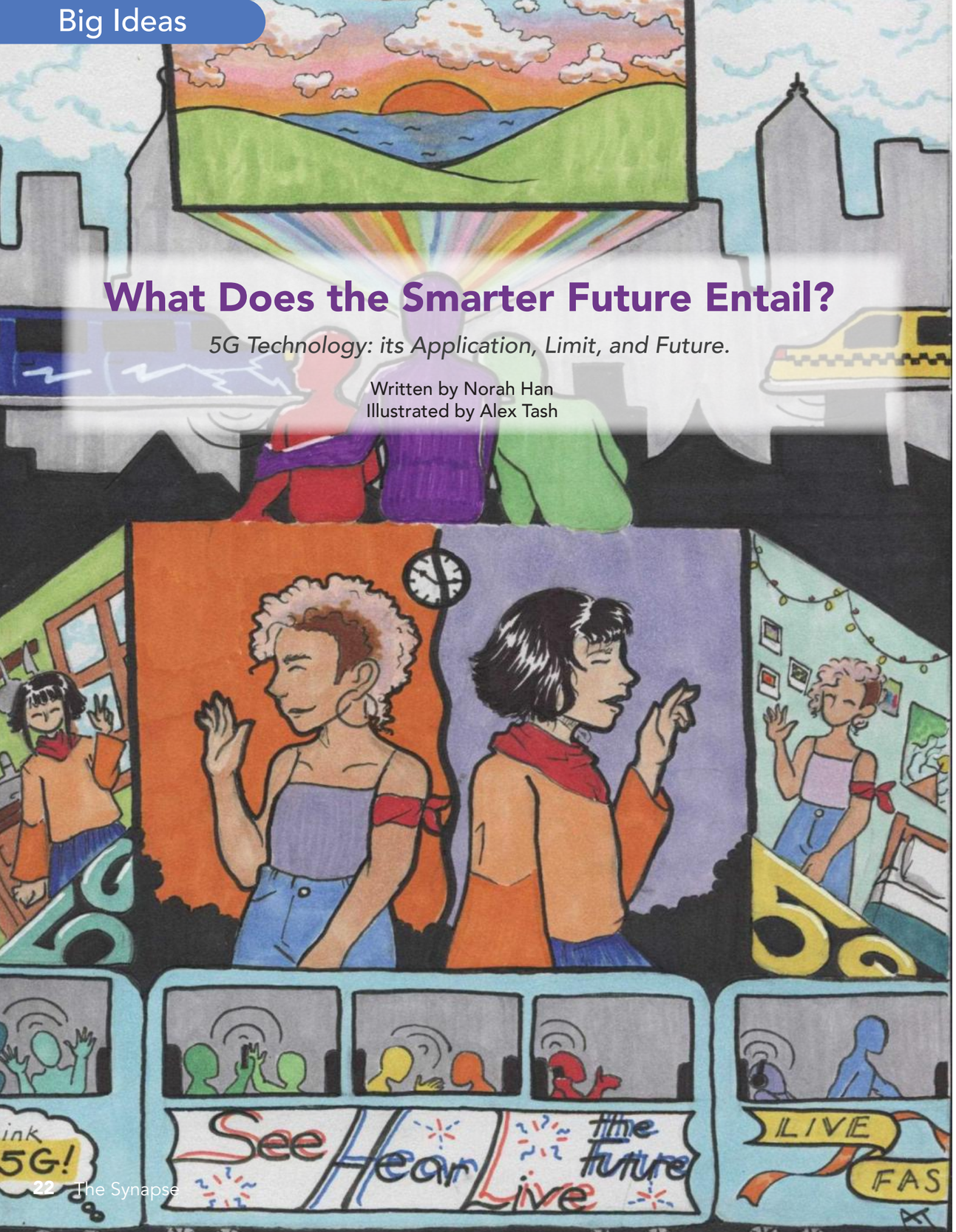
factors into its analysis. This avoidance harms public awareness in developed countries like the US because authors dismiss how the environmental efforts in poorer regions are motivated by poverty, hunger, and thirst. James Temple exemplifies this dismissal in the MIT Technology Review. Though professor Ermias Kebreab had led research to mitigate "recurrent droughts and famines" in Eritrea in east Africa, Temple devoted most of his article to explaining how Kebreab's discovery of a type of algae reduced cattle's methane emissions. By downplaying how the context of poverty and unreliable food sources occupy the priorities of other global regions, Temple underemphasized how the capacity for improvement is limited to developed, wealthy regions.

In The Guardian, Damian Carrington's argument for reducing meat and dairy consumption reiterated a common point that cattle are both inefficient at producing protein and demand a lot of land. He reported that meat and dairy production occupied three fourths of the world's agricultural land, or "an area equivalent to the US, China, European Union and Australia combined," and that without meat and dairy, the remaining quarter of land could "feed the world." However, he didn't note how at the same time, cattle are well adapted to support people in developing countries. Gerber explained that in regions with "particularly harsh climates" and "poor feed quality," cattle's physical hardiness can "sustain livelihoods and human settlements," and that sometimes cows are culled late "to [buffer] against shocks and crisis." In addition to being resilient, cattle can also serve a number of functions, such as "transportation, fibber, banking, and insurance." Still, developing areas don't have enough protein to sustain them. According to the WRI's full report, regions where farm animals don't efficiently put on weight are experiencing a rising demand for meat. Cattle's high land demand then specifically damns beef in food secure areas, because developing countries depend on cattle.

Along the same train of thought, Carrington also didn't address that poorer global regions can't always improve their production practices. The WRI's full report adds that developing countries don't possess the finances or infrastructure to reduce their emissions. Four fifths of global farms are less than five acres and have trouble making "productivity improvements" and meeting "tight sanitary and quality standards." Considering that eighty percent of the world's farms don't have another choice, the need for the US to improve becomes even more pressing.

While reducing US beef consumption is imperative to meeting the WRI's three "gaps," the US needs to make other changes in its beef industry. Just as environmentalist articles will exclude global socioeconomic conditions, they will also exclude the national socioeconomic contexts of production methods. When Foley compared methods of US beef production, he argued for reduced consumption because of feedlot's high levels of pollution; he claimed his goals were, "to eat less, waste none, and try to source it from grass." But Foley did not address that undocumented workers and refugees are most impacted by pollution and have the most to lose from American beef feedlot's shrinking profits. As Nick Miroff explains in The Texas Tribune, US meat facilities typically have difficulty finding enough workers, so they hire undocumented immigrants and refugees. Employees who don't have citizenship status and therefore legal protection are already in precarious financial situations. If US beef producers have a significant reduction in gross income, undocumented and refugee workers are prone to financial harm. Miroff's article also reflects how these immigrants and refugees live close to their workplace, as meat processing plants monetarily power their surrounding town. Miroff quotes a city manager saying "Cactus [the town] wouldn't exist without the plant." Because workers live so close, they are most affected by the "manure runoff, water pollution, air pollution, and noxious odors" Foley names as principal impacts. While we need to eat less beef, we also need to continue to support the undocumented workers and refugees that produce it. One solution for this could be paying more. More importantly though, we must find a way to produce less beef while allowing structurally disadvantaged workers to stay healthy and paid.

If Americans are to aid humanity in securing a "sustainable food future," we need to reduce our overconsumption in consideration for our global, national, and cultural impacts. Popular environmental arguments are not working because they do not explain the connection between the environmental costs of consumption in developed countries and the dietary and structural inflexibility of undeveloped countries. Nor do they account for the lives of the systemically disadvantaged workers who work in agricultural facilities such as feedlots. They do not account for the United States' cultural power either. As a developed country that largely subscribes to western culture, an American challenge of beef's symbolism for wealth and wellbeing could rebound and slow the conversion of other countries to meat and dairy intensive diets. In order to effectively improve the US beef industry, we must make our perspectives more inclusive, and change what we commonly understand as an environmental problem to a human one. • • •



What Does the Smarter Future Entail?

5G Technology: its Application, Limit, and Future.

Written by Norah Han
Illustrated by Alex Tash

Have you ever wanted Tony Stark's Jarvis robot? Or dreamt of sipping your morning latte while downloading an HD movie in seconds, all from a self-driving car? That's the magic of 5G, the fifth generation of wireless technology. One of the fastest technological inventions in the world, 5G promises quicker downloads, outstanding network reliability, and an immense influence on how people live, travel, and communicate. We are going to explore the infinite possibilities behind 5G: how it propagates the development of Internet of Things, enables true high-resolution video streaming without any latency, and makes the dream of immersing ourselves in an augmented reality world come true.

Before 5G, there were four generations of mobile network. The first generation (1G) had a limited bandwidth of 2.4 Kbps and only supported voice calls. Next there was 2G, which enabled SMS and picture messages, and had a maximum speed of 50 Kbps. Then 3G, first introduced in 1998, made video calling and other mobile functions come true. Finally, the 4G network was developed. Not only did 4G have the features of 3G, but it also enabled gaming services, HD TV, and video conferencing by providing a max speed of 100 Mbps.

You might ask, "Then how big is this leap in data transmission?" Launching 5G is like constructing an airport in a metropolitan area. Not only does it ameliorate the problem of data transmission latency (total time the data requires to be transferred from one device to another), but it also opens the gateway to new technological advancement such as Internet of Things (IoT) and improved Augmented Reality (AR) experience.

IoT technology will bloom along with 5G. IoT, in brief, is a system that connects computing devices embedded in everyday objects that send back data instantaneously. We will see a significant change in our lives – more than 75 billion devices connected wirelessly before 2025. Take the self-driving car as an example. Multiple

> If we compare our mobile phones to cars driving on an increasingly crammed highway, then 5G technology is the newest solution to the traffic jam.

sensors installed on the car, around the city, and on your phone will be able to form an invisible, sensitive, and self-operational system that makes features such as automatic parking and wireless charging (for electric cars) come true. To enable the operation of such large-scale systems, the transmission of data takes up energy as well as time. By providing higher speed connectivity, however, 5G resolves this problem. It becomes possible for these intelligent cars to constantly collect multiple types of data. Therefore, the algorithms that operate autonomously keep track of the car's traits and provide suggestions to future designs.

Though Augmented Reality (AR) is already a prominent part of today's society, its future development relies heavily on the capacity of data transformation. Do not confuse AR with VR. Virtual Reality (VR) seeks to create a new digital world within our current reality, while AR aims to embed virtual components in the real world. However, in order to knit the real world tightly with the internet, data must be transferred between both sides instantaneously. This restrainment "spell" is broken by 5G. According to ABI research, 5G has "10X increase in throughput, 10X decrease in latency, and 100X increase in traffic capacity." AR will become more accessible to the public. For instance, smart cities is one of the novel ideas that might be applied to real life via 5G. The mechanism behind smart cities is to synthesize large amounts of data collected by sensors in city infrastructures, then stream them to multiple intelligent systems. These systems are able to "talk" to each other, therefore enabling instant, effective response to the management of traffic systems, water supplies, libraries, schools, and other services.

The birth of 5G technology brings a promising future, however, there are three major limitations that should be taken into consideration. Firstly, the cost makes it less practical. Due to the signal's frequency, wavelength, and latency, a 2G cellular base station has a coverage of seven kilometers, a 4G base station covers one kilometer, and a 5G station's range is only 300 meters. Therefore, if countries and companies desire to make 5G more accessible by constructing more base stations, the expenditure will escalate. Another concern is that the power consumption of a 5G base station is "Three times that of its 4G LTE predecessor," according to Zhengmao Li, the Employee Value Proposition at China Mobile. Moreover, for the applicability of 5G, there is still room for improvement. Before IoT and AR are popularized, the influence of 5G on the individual customer is limited.

5G is not merely a technological advancement. Its economical and political influence on countries and private firms should not be overlooked. Most of the developed and developing countries' growth is heavily reliant on technology. However, 5G can be a double-edged sword. Like all the other innovations, it is a key factor that triggers new businesses and promotes international trade. The country or company that leads the world in the adoption of 5G technology will have a distinct technological, economic, and security advantage. According to the United Nations' report on "Leveraging Technology and Trade for Economic Development", Netflix is "reported to be one of the most valuable media companies in the world, with a market value of $152.6 billion on 24 May 2018, and the company revealed that its current membership level was 125 million subscribers at the end of first quarter of 2018." On the other hand, the gap between leading countries and the rest might be widened. Therefore, it will be even more challenging for some countries to achieve economic growth. For them, foreign technology might mean not being provided with complete information or up-to-date technology. Therefore, a country's capability to innovate independently is crucial to its leadership in international technology.

As more people are connected to each other through the Internet, our world has become more globalized than ever before. Inevitably, countries will have to become allies with each other in order to sustain a positive and mutually beneficial relationship. In my opinion, instead of turning the research of 5G into an invisible war, both countries and their people might be better off if they are open to sharing. • • •

DNA Origami

A Nanodevice with Mega Potential

Written by Aaron Morales Dolich
Illustrated by Logan Wallen

Can DNA be used as a machine? With the development of DNA origami, it is used as a nanodevice in numerous applications. Over the summer, I researched protein interactions of DNA origami at Ohio State University, and I was amazed to learn about its many functions. These functions can range from drug delivery to nanorobotics, but the possibilities of this nanodevice are endless because its novelty. This new DNA device can particularly be used cancer treatment and in bioanalysis.

In 2006, Paul Rothumed proposed the first design for DNA Origami. To make the origami, you need a long circular strand of DNA (a "scaffold"), some shorter strands of DNA, a protective solution that's mainly water -- a buffer -- and time. Eventually, the shorter DNA pieces will attach to the scaffold and produce a sculptural structure, like origami, the Japanese art of paper folding. This was originally used as artwork: scientists made stars, smiley faces and even a map of China with their constructed DNA. However, the applications hardly stop here: research was then conducted as to its applications in medicine.

One exciting application of the nanodevice is in drug delivery. Doxorubicin (Dox) is a common chemotherapy drug that kills tumor cells by literally inserting itself into the DNA of a tumor, and obstructing its growth. However, there are numerous adverse effects, one of them being that tumors can develop resistance to Dox. DNA origami though, can circumvent resistance to Dox by targeting the primary mechanism of resistance. One of the most common ways for tumor cells to become resistant to drugs is to inhibit the uptake of drugs, preventing it from being absorbed through the cell membrane. However, Jiang and colleagues demonstrated that DNA origami constructs loaded with Dox developed the biocompatibility of the nanodevice. Unlike other Dox delivery services, the biological nature of the nanodevice allows it to enter the cell, much like a mole infiltrating an enemy spy group. They found that the uptake of Dox in resistant human breast cancer cells was size and shape-dependent. The origami indicated massive potential as a therapeutic because the cancer cells had an increase in uptake of Dox. Because of this circumvention, DNA origami shows great promise are a potential treatment if other studies are succesful.

> The biological nature of this nanodevice allows it to effectively kill drug resistant cancer cells.

DNA origami is also applicable outside of the field of medicine. One of the most significant applications for DNA origami is in bioanalysis, the quantitative measurement of biomolecules in biological systems. One reason for the surge of origami research is its ability to control the distance between molecules on binding sites with a super-fine resolution. This works because binding sites can be imagined as wells in a 3D platform structure. In fact, in this application, DNA origami is literally a platform to build molecules. Under an advanced microscope, we can see finer detail when studying DNA when it's in an origami manifold made specifically for this task.

DNA origami can also be easily customized for single-molecule kinetics experiments. These are experiments where we observe how molecules bind to DNA on the nanodevice platform on a literal single-molecule level. These experiments operate within an interdisciplinary rubric -- at this molecular level, biology, chemistry, and physics are difficult to separate. However, this cannot be done with origami alone; we need to use fluorophore techniques. Johnson-Buck and colleagues utilized these techniques on a single-molecule level to measure how a single-stranded oligo (synthesized DNA) attached to DNA origami affected the kinetics of attaching to its complement target strands. This type of kinetics work with DNA has been utilized by other scientists to study distance interactions with more physiologically relevant molecules.

Over the summer, I researched interactions between oligos and transcription factor (TF) protein found in yeast (Cbf1) using DNA origami. I looked at the distance between binding sites on DNA origami and affinity, or attraction, of Cbf1. Our research was informed by Ben Donovan, who researched Cbf1 accessibility of nucleosomes. Donovan's goal was to understand how Cbf1 binds to DNA when nucleosomes restrict DNA accessibility. Nucleosomes are the skeletal structure of DNA in eukaryotes, including plants and animals, that prevent Cbf1 from having easy access to DNA. This happens because DNA is wrapped around proteins in nucleosomes, which block binding sites from TFs. The research demonstrated that the proteins bind to sites within nucleosomes with a high affinity but dissociate from nucleosomes ~25 fold slower. This gives us an idea as to how TFs bind in cells, but we believe DNA origami can give us a similarly accurate reasoning.

When TFs like Cbf1 bind to gene, they increase the likelihood of gene expression. Their mechanisms for binding are not as well understood due to the density of the cytoplasm, or cell fluid. DNA origami analysis addresses the problem of the density of the cytoplasm by allowing for DNA binding in vitro (outside of a cell). This allows for control of both distance between binding sites and the amount of binding sites attached to the origami structure. The implications of this field of research are that we can now better quantify affinities using DNA origami. From these, we can also solve other problems such as thermodynamic quantities.

DNA origami has nearly limitless potential and could be groundbreaking for a multitude of scientific fields. We can modify DNA with other pieces of DNA and use it for practical applications. The most exciting ones are in drug delivery and bioanalysis. The biological nature of this nanodevice allows it to effectively kill drug resistant cancer cells. Specifically, the nanodevice is biocompatible with the cell and bypasses the shape and size-dependent barriers of the cell where other delivery methods fail. DNA has contributed most significantly to bioanalysis. With the aid of fluorescent techniques, we can observe how biomolecules interact on an Angstrom scale and be able to control how the molecules bond to the platform and to each other. Techniques in electron microscopy can verify this. Fluorescence has also proved effective in providing researchers a tool to determine the kinetics of target strand binding to an oligo assay on an origami platform. DNA origami has already changed multiple disciplines and its development and later use will be thrilling to watch. • • •

Anchored

Written by Sophie Lyon
Illustrated by Roger Ort

Pila's arms shook as she pushed herself up off the sandy floor of the Battledome. Her battleaxe had been flung yards away, far out of reach. The battle was lost, but she refused to lose with her face in the sand. She turned to see Lionheart standing above her, the blade of her broadsword propped over her shoulder, glistening dark red with Pila's blood. Lionheart smiled, casually flicking up the visor of her helmet. "Not so mighty now, are you?"

Pila's voice came out in a rasp. "Stop gloating, Lionheart. Next time it'll be your head on the chopping block."

"Maybe." Lionheart flipped her visor back down, raising her sword. "Next time."

Feeling the weight of her necklace against her collarbones, Pila murmured a silent prayer to Anchor, hoping her whispers couldn't be heard over the roar of the crowd. She knew Anchor did not rule here, but maybe he could make the pain swift.

Lionheart brought the sword down on her neck.

Pila woke with a start, the feeling of Lionheart's blade still tingling through her neck. It only took her a moment to remember that the fight was nothing but a bad dream written by the Battledome programmers. She was alive, but still held within the simulation in a room where she could rest until her next fight. Entertainment without casualty. Watching the fights as a child she never thought that one day it would be her fighting in the blood-soaked sand. She never could have imagined how real the digital fight felt. Her body was safely stored in the medical bay, hooked up to wires and tubes that kept her corpse alive as she fought. Shivering at the memory of the fight the night before, Pila said another prayer to Anchor, thanking him for the quick death and asking forgiveness for how meaningless all the dying and killing had become. As she prayed, she went to touch the string of beads around her neck but when she reached for them, she found her neck bare.

Silently, she laid the palm of her hand over where the beads had once rested. It was far overdue and she tried to convince herself it was no major loss. The string of beads she had worn for almost two years was only an illusion, although it had been a comforting one. Pila racked her mind for something that could have tipped the programmers off. Had she touched the beads one too many times subconsciously during battle? Did someone recognize them? Or was it just a stroke of bad luck: a meaningless decision by the costume department? Pila's neck felt oddly bare under her fingers. She would not be getting the beads back. If she wasn't punished for wearing them in the first place, she could consider herself lucky.

Years ago, Pila had stood out in the yard with her father. She slipped through the gate, moving quickly so as not to let any of the chickens out. Fidgeting nervously, she watched the chickens peck feed she'd just spread on the ground. Her eyes fell on a particularly round chicken with beautiful orange-brown feathers. Pila looked to her father for approval, but he stayed silent. They both knew this was something she was meant to do herself.

Slowly, she walked up to the chicken. It took a few steps away, pecking from a farther bit of feed. Pila lunged, but landed in the dirt instead of grabbing the chicken. The yard was sent into a frenzy, wings flapping, birds squawking. She pushed herself up off the ground.

"Slowly, Pila."

She nodded. Her bird hadn't gone far in the chaos, but it was more cautious now, not allowing her to get close enough to grab. She approached slowly, heart banging against her ribs. When the coop had returned to its restful state, she quickly grabbed the bird, pinning its wings to its body so it couldn't flap.

The gate was harder to open with a chicken in her hands, but she managed to get through without losing her grip. The feathers looked beautiful in the morning light, shining red like the last dying flames in a bed of embers. Pila approached the old stump by the side of the house with the chicken clutched close to her. She thought she could feel its little heart beating in its chest, but then again it could be her own pulse thrumming in her fingertips. She had split wood a thousand times on the log under her parents' watchful eye. She stared at the axe. "I —" Pila's voice was embarrassingly weak. "I don't think I can do it."

"You've eaten chicken your whole life, Pila."

"I don't want to kill it..."

"It's different when you're the one with the axe, isn't it?"

She nodded, fighting tears.

Pila held the chicken down on the block and wrenched the axe from the wood.

"Don't hesitate. If you do you may not kill it on the first swing. You don't want it to suffer."

The bird still looked so beautiful. Pila wondered, her axe raised, if this was one of the chicks she watched hatch two springs ago. Their feathers had been so soft when she held them for the first time. She was out every morning to feed them, and every day they grew with her. Pila felt the feathers of the grown hen under her palm and said a prayer to Anchor with words she didn't understand, but whose meaning she was finally beginning to grasp. There was no hesitation in her swing; the blade cut clean through the head and down to the wood below. The body thrashed for a few moments after death, muscles still contracting and nerves still firing. Pila held the body down as it struggled for a life already lost, her stomach in knots. She said another prayer, thanking it for its life, staring unblinkingly. Finally, the body went still.

She tracked blood in the house when she brought it into the kitchen. While she waited for the water on the stove to heat up, she washed the dirt from the vegetables she had collected from the garden earlier. After dunking the bird in boiling water, Pila ripped out fistfuls of feathers from the scalded skin with ease, carefully collecting them to be used in a pillow. While gutting the bird and cutting its feet off, she still felt the weight of the axe in her hands. That which could be eaten was put in the oven, carefully seasoned with fresh herbs and nestled in vegetables.

Pila enjoyed dinner, singing a few songs for the special occasion with her family. The chicken wasn't perfect, but it was good, and there was plenty of satisfaction in knowing that she had done it all herself. Pila led another prayer thanking the bird and thanking Anchor for the meal.

After the meal, she took a few of the bones and carefully broke them so only the ball joint remained, throwing the rest into the pot for stock. They were then tumbled like stones, until round and smooth, looking like beads of pumice. The bone wasn't ideal. It was nowhere near as beautiful as the stag's horn that her mother wore, or as sturdy as her father's cow bone, but she wanted her first deathbringing to be one of the chickens they raised. She poked a hole through the spherical bits of bone and strung them on a length of handspun string, which her parents then tied around her neck.

The beads stayed there, yellowed from years of being touched, but well cared for, until she was sent to the Battledome. She stripped down, leaving her necklace for last. The guard nodded his head towards it. "That too."

I can't. She wanted to beg. Everything else but not this. Still, she obediently went to untie the string. The guard watched her struggle with the knot, naked, trying desperately to dig her short nails into the thread. The knot wouldn't come loose. It wasn't meant to. He only let her work at it for a minute before reaching out to grab it, a pair of scissors in hand.

"Please." She drew back, trying to keep the desperation from her voice. "Let me." The guard put the scissors in her open palm.

They cut easily through the old string.

Pila coiled the necklace carefully on top of her pile of clothes. The guard unceremoniously tossed a medical robe at her and left, taking the beads with him. The necklace was gone.

When she entered the Battledome a few hours later, their comforting weight was back. Imagined, but just as real as anything that Pila had left.

Pila allowed herself to lay in bed a minute longer, palm on her bare neck. She shut her eyes, feeling her chest rise and fall slowly under her hand. It was no true loss. The real beads were long gone, hidden away in a different world. Anyway, it was only a necklace. • • •

Bo and Linda Arbogast

Interview by Emma Larson
Photos Provided by Bo Arbogast

Bo Arbogast is the Assistant Dean for Student Support at Oberlin College, and Linda Arbogast is the Sustainability Coordinator for the City of Oberlin. They also happen to be long-time organic blueberry farmers. You can pick your own blueberries at their farm, Chance Creek Blues, located in Amherst, Ohio. We at *The Synapse* are excited to share more about organic farming practices and these unique community members.

This interview has been edited for length and clarity.

How long have you all been in Oberlin?

We've been here for sixteen years. We moved here from New Jersey where we were living for five years. We moved here for a job that I was offered at the Bonner Center. I was the one of the first directors of the Community Service Work Study Program. The College had just gotten the learning service grant from the Corporation for National Community Service and they hired me for that. It was a short-term grant funded job. We moved and sold our house and came here, a lot of people were like, "What? Why would you do that? Uprooting three kids..." But yeah, we ended up buying the blueberry farm as we were house hunting.

Where does the farm's name come from?

It was named by a student. When we bought the farm it was called Twin Oaks, and it had been being run organically so it hadn't had a lot of management in recent years, and we kind of wanted--Well one) the oak tree had fallen, so there was no surviving oak, and two) we wanted a name that we felt represented the place. So I was asking students at the--it was called the Center for Service and Learning at that time, and one of my students, Elana Riffle... I had lots of ideas at first but hers was like YES! Chance Creek Blues, so that's where the name comes from... Because Chance Creek is right there, and Bo is a musician so adding the music into it... And then blues sort of having double meaning blues, blueberries.

What is an average day in terms of farm activities?

Farming is very episodic: harvesting time, planting time, pruning time. This is our lowest season. Pruning is… That's the biggest endeavor. We've got a thousand bushes, and we have to prune every one, about a third of the stocks, so that adds up. It's a multistep process so you have to cut the canes, pull out the stuff and then pile up the sticks. Then you have a thousand piles of sticks. So we actually have a big pruning part every year in the winter, February or early March, on a good day, sunny day. We need about 20-25 people to help cut all everything. Human labor is the best because you have to get in between bushes and around the sides. You can't just run cranes in there. We use tarps, so we toss them on the tarps and we try to have a lot of tenagers in the mix. It's usually our friends. We try to get people to bring their kids and we try to get our kids. So that's the big enterprise in the winter but then there's fertilizing in the spring. There's a group called Ohio Earth Food. It's a really cool organization that helps farmers figure out how to be organic and how to be sustainable. We've worked with them the whole time that we've been here. We do soil tests, we send it to them and then they talk us through what inputs would help, like if we need nitrogen... We have a lot of things that we need to put on the bushes based on our soil test. It's more labor intensive.

How often do you do soil tests?

We used to do it every year but now we do it more like every few years. It didn't seem to be something that we needed to do every year. It let's you keep up on blueberries for acidity. It's important to know the acidity of the soil and to change that as things go awry. The pH is supposed to be like 4.5 or 5, we get up a little past that but I think we are in a naturally sort of acidic soil in the glacial till area. It's all around us but blueberries need an even more acidic environment.

Has this been a good year as compared to previous years?

It was pretty good. Last year it was a challenging year. It was pretty dry and we dont have an irrigation system so we are dependent on the rain and that changes... It's challenging. This year we had a really wet spring which is good for us, so the more rain the better really.

Have you ever thought about putting in an irrigation system?

Oh we think about it all the time. All the time, every dry year. It's so complicated though because, talking about the mowing, so if you put it on the ground, then it can break and you can't find it... There are just so many challenges. We saw a farm in Michigan where it was in the air sort of at eye level, so you could get under it, but even that is difficult. Most years we've been okay. We knew whatever we invested in irrigation would pay for itself in our second crop. During those years that it is drier, it's super frustrating. It's sad because you've worked all season and then no... It's never good.

Do you have different varieties?

There are seven. We couldn't really tell you their names. We know some of the names but we didn't actually ever get a list. Those bushes are over fifty years old. But over the years, every year we plant some. You can find cultivars that are early, mid season, late season. We kind of have to do a mix so that we can keep it going.
Cultivar is the word for the different varities. Apparently the previous owners left us a list but... Or did they? We never saw it. You can dig in and see a little metal tag on some of them. There's a lot.

What do you see for the future of Chance Creek Blues?

Climate change is an issue that we think about, because you can't grow food without water. So that change, it's already changed. There's old normal, new normal. It used to be the end of June, that's when the blueberries came, but it's been the middle of June for us almost the whole time that we've been here. Late June, early July was the start of the season and it's been mid June almost every season we've been here except for one.

Would you say that the season is getting shorter?

No, it's starting at a different time but as you might know that affects everything because, suppose you have a natural predator, or you have bees that pollinate, everybody gets synced up, so if it's two weeks difference... With blueberries it doesn't make much difference because we have different varities, but if it's three weeks different, now they're starting to--the buds are coming earlier than the bees are here. They're budding out but then there are no bees because it's not sunny and warm. So we've had years of really bad pollination. We try to keep a lot of wild flowers all around to keep the pollination going. Our neighbor has honey bees so that helps but native bees are better pollinators.

What would you say about your relationships with other farmers?

People are pretty friendly. It was rough at first because we were the only organic in the area and we got a lot of hard sell of like "No you can't do it, it's illegal," because we are not certified, because we are small and there are rules about size and production. We still follow all of the same practices. Because we were new to this we did a lot of research and so we knew we were okay but we got a lot of flack. Made people look bad I think. We charged more and we were open about it and then I think our reputation got, people were like "Yeah sure, they're legit." We weren't arrogant, we weren't fly-by-nights. They figured like "Ah you guys will last two years," so they just kind of dis you. We were respectful, plus we send people to other places like "Oh you're here and you want other fruit?"

Do think that's still the case for people just starting out?

I think it's always hard in a farming community. People are always skeptical of the new comers. Especially people who are doing things differently, and seems like "Hey I've been here my whole life" and "Don't you be telling me how this goes." I mean I grew up on a farm I know that mentality, I've heard it from my family. We all need to be thinking about our food systems because it's so much harder and bigger and challening. So I'm the sustainability coordinator for the City, and one of the issues is trying to increase how food is grown and doing home gardens and community gardens... As long as people are following the rules and keeping the invasives out and planting the right things, just finding that balance of tradition... But at the same time we have to do things better and plant for pollination.

How do you and other farmers view the scientific community?

I think that the Ohio Extension Service is really valuable to farmers, and I think that's the connection to the scientific community. When a pest shows up, you call your extension. When we were new we had an OSU guy Charles, he came and we didn't know anything. He was an RPBP research volunteer. It's an extension agency so even in Lorain county we have one, every county has one. There's the extension, the Farm Bureau... It tends to be more political than scientific but they also do some training. I think the extension agents are the lifeline for a lot of farmers, in terms of what's new, what the new pests are. Organic or not they really do good work.

Do you ever get tired of eating blueberries?

No, I don't think so. Our kids have a kind of reserved pride about them. It's a unique thing to have in your background... It's always been a very social thing for us.

Sparkling Bog

by Roger Ort

Meet *The Synapse*...

...at Oberlin

Pictured from left to right, back to front: Emma Larson, Rebecca Fenselau, Steven Mentzer, Miranda Marnik-Said, Victoria Fisher, Evelyn Morrison, Rachael Branscomb, Yue Yu

...at Denison

Pictured from left to right: Casey Pearce, Kileigh Ford, Elizabeth Toigo, Delaney McRitchie

/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.