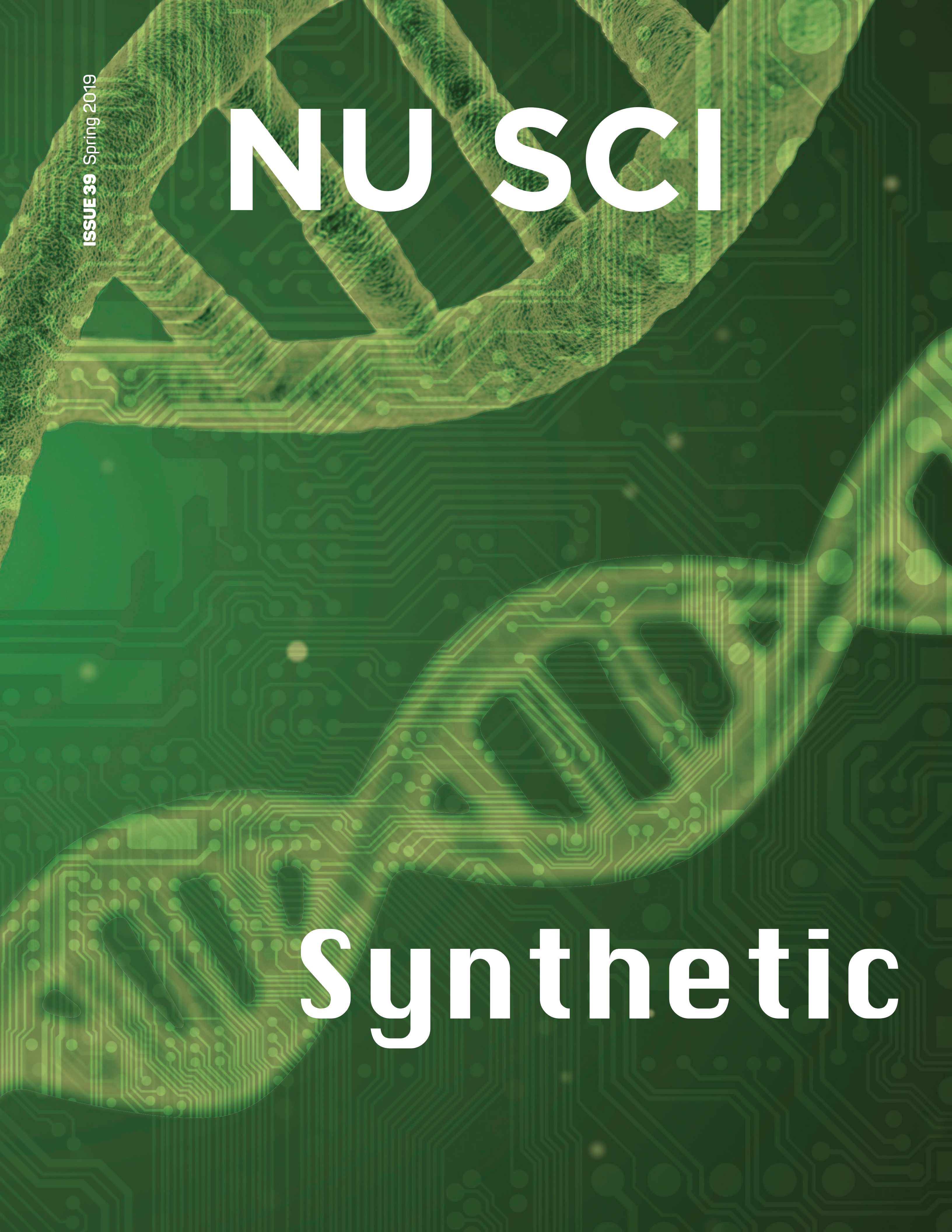

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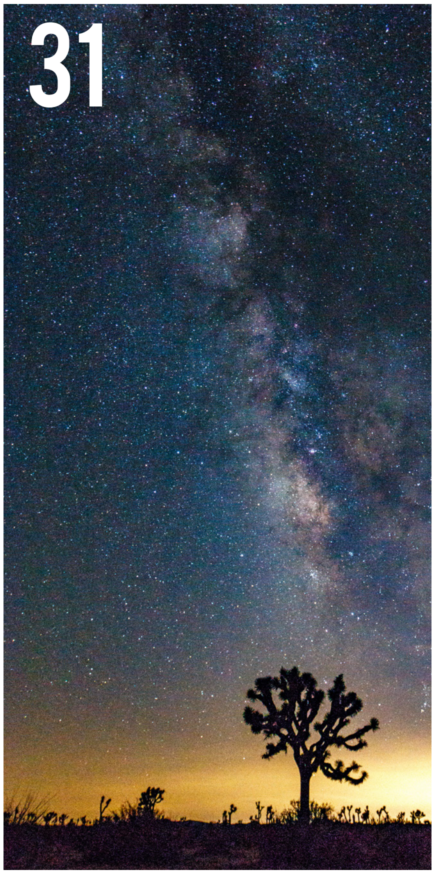


LETTER FROM THE EDITOR

This semester kicks off the 10th year of NU Sci. Throughout the past decade, our publication has evolved so much: we changed our title from NU Science to NU Sci, the print magazine from black-and-white to color, and from printing 18 to 36 pages per issue. We are excited to spend the year celebrating how much we've grown since 2009, and the hundreds of writers, designers, webmasters, marketers, and articles that have propelled this publication.

Each issue, we spend several meetings brainstorming our theme—always working to pick a broad word that can encapsulate every field and identify current trends in science. This time, we went more literal than we have in the past to choose a theme; one that is at the forefront of innovation and scientific possibility in almost every discipline imaginable. We hope the chosen article topics teach you something about incredible, new technologies being utilized and inspire thoughts and discussion around what it means for our society to use things like robots and man-made cells.

And so, to kick off our 10th year of publication, I'm proud to introduce Issue 39: Synthetic.

Read about the CRISPR twins, synthetic cells, bioplastics in the environment, or robotic chemical printers that can produce drugs—these are just some of the wide variety of topics we'll cover in this issue.

I'd like to give a special shoutout to our most unique article this issue. In collaboration with The Avenue, Northeastern's premier fashion and culture magazine, our writers discussed sustainable fashion, the use of synthetic materials, and the challenges both companies and consumers face devoting themselves to sustainable materials. Accompanied by a photoshoot with our new photography team and a brilliant effort from members of The Avenue, we are so excited to publish this piece, and we hope it will be the catalyst for future collaborations with other campus publications.

It's sometimes hard to see, but we have behind-the-scenes operations running for every component of our magazine. I love seeing the teamwork, creativity, and time commitment that each one of our e-board and specific team members puts in to help us make and share our publication. Thank you so much to everyone who has a hand in making NU Sci possible through every roadblock and new opportunity.

And with that, we can't wait for you to explore all things synthetic!

Sage Wesenberg
Editor-in-Chief

STAFF

Cover Design by Kyla Vigdor

The life of an estuarine ecologist:

An interview with Dr. Rikke Jeppesen, Elkhorn Slough National Estuarine Research Reserve

BY LUCAS PRINCIPE, ENVIRONMENTAL SCIENCE & PHILOSOPHY, 2020

Elkhorn Slough National Estuarine Research Reserve (ESNERR) is a 1700-acre wildlife reserve located in central California—an area where abundant estuaries once lined the coast, but are now concentrated in small, scattered pockets. ESNERR is part of the National Estuarine Research Reserve (NERR) program—an initiative funded by the National Oceanic and Atmospheric Administration to protect and monitor baseline water quality in 29 estuaries around the nation. Reserves such as these are staffed by professional scientists who work for the government instead of a university or research and development company—a conscious career choice; one that seems to be infrequently spoken of at top research universities and may be appealing to many undergraduate STEM majors. Dr. Rikke Jeppesen of ESNERR is one of these scientists. I sat down with her in January to talk about what the life of a government scientist is really like.

Jeppesen's official title is "Estuarine Ecologist." Her work primarily deals with water quality, environmental monitoring, and restoration projects. She started at the Slough in 2006 while finishing her PhD in Ecology and Evolutionary Biology at the University of California, Santa Cruz.

As members of the NERR program, ESNERR scientists are required to collect data on everything from aquatic nutrient content to weather parameters. At first, this description may make the job sound tedious and invariable. However, it's a bit hard to nail down what the daily routines are, mostly because, she says, "I don't really have daily routines. I have weekly routines," each one varying by day and season.

For example, on Mondays Jeppesen travels to various locations within the reserve switching out field instruments. Tuesdays are usually dedicated to processing the copious amounts of data the team gathers. Wednesdays and Thursdays are filled with meetings and planning for the various research and restoration projects taking place at the reserve. And Fridays, Jeppesen says, "I kind of get to do whatever I want. As long as its relevant." These days are typically spent catching up on old assignments and conducting fieldwork—particularly in the summer.

Another large part of the job involves working on separate research and restoration projects. At the moment, the biggest project the ESNERR team is working on is a restoration of over 100 acres of marshland. The team successfully worked with contractors, local scientists, and nearby stakeholders to raise the elevation of a marsh that had sunk significantly due to decades worth of draining, diking, groundwater overdraft, and other anthropogenic activity. The low-lying marsh became too inundated with brackish water to support a high level of marsh-plant diversity—a factor key to marsh health. The team's plan was to add large amounts of sediment, increasing the elevation of the marsh plain to enable increased plant cover of the most abundant marsh-plant species—pickleweed—and to allow a broader diversity of plants to flourish.

Jeppesen says she thinks the ultimate goal of ESNERR is to restore the habitat in the Elkhorn Slough watershed. "In order to achieve that goal, we have to do monitoring, we have to conduct research so that we can inform our restoration efforts. We also have to work with stakeholders in the area. If we just do whatever we want without the neighbors' input, we could get a lot of complaints and we may not get our permits."

As one would expect, Jeppesen views working at the Slough as an incredibly rewarding career. Much of the staff scientists' work involves the help of curious, driven volunteers from the surrounding areas to collect data across the massive reserve. "Even though they're not scientists themselves, they want to help and they are interested and engaged and ask good questions," says Jeppesen. "Working with people in that mindset is just fun."

Though the most fun part of the job, she contends, is solving complex ecological problems. "The thing that's really fun is that no one is giving you a solution, you just have to figure it out. We have these very different people with these very different skill sets. If one person did it alone, maybe they could do it, but probably not. It's fun to work as a group where we can all contribute to different things, and in the end the result is so much better than if you did it by yourself."

She also added, "It might sound like fun to some people to jump around in the mud all day. And it is. It's nice to be outside. It's a lot of hard work though."

DESIGN BY KRISTI BUI, COMPUTER SCIENCE, 2021
PHOTOS BY RIKKE JEPPESEN

THE CROWN PEARLS OF NEW YORK CITY

BY SINAIA KEITH LANG, BIOLOGY, 2022
DESIGN BY KYLA VIGDOR, DESIGN, 2021
PHOTO BY PIXABAY

Skyscrapers shook, branches blew off trees, and transformer explosions left hundreds of thousands of people in darkness for days. This was no attack; this was Superstorm Sandy as it battered New York City in October 2012. Massive storm surges sent cars floating out of parking garages, sparked electrical fires, and even moved a roller coaster into the ocean in Seaside Heights, New Jersey. Recent projects seeking to mitigate these flood damages have found an unlikely biological ally: oysters.

While the ethics of human intervention in the Earth's climate, also known as geoengineering, is being debated, several organizations in New York City are taking a geoengineering-natural history hybrid approach to protect New York from storms that are worsening as a result of climate change. Since 2014, The Billion Oyster Project has worked to restore the oyster reefs that created natural breakwaters (barriers underwater that lessen the effect of storm surges) and kept the water in New York Harbor clean for centuries.

When European settlers arrived in what is now New York City at the beginning of the seventeenth century, oyster beds composed 350 square miles of the lower Hudson River. Some estimates say, at one point, the New York Harbor contained half of the world's oysters. The ubiquity of oysters in New York's food—from fine-dining to street carts—made the bivalve mollusk practically synonymous with New York. This ubiquity had consequences, however, as the nitrogen-filtering oyster population plummeted from overharvesting. This, combined with industrialization, caused the waters of the harbor to become extremely polluted.

Oysters are filter feeders, meaning they ingest and filter about 50 gallons of water per day and retain the nutrients they need. Nitrogen pollution, which promotes algal growth that reduces the oxygen levels of the water, is removed from the water by oysters via the ingestion of contaminated water, and the subsequent deposition of pollutants as a solid packet in the sand and storage of some of the nitrogen in their shells and tissues. Wild oysters have especially thick shells to protect themselves from predators. This means that fostering natural oyster growth, as opposed to relying on oysters hatched in labs, can increase the amount of nitrogen filtered out of the water.

The Billion Oyster Project has been fostering natural oyster growth by placing artificial reefs, all of which have baby oysters that have been attached to recycled oyster shells, in the water. The empty shells come from the dozens of restaurants that have partnered with the organization and the baby oysters are hatched by students at the New York Harbor School, a public high school on Governors Island that specializes in nautical activities. These reefs can be added on to by wild marine life, allowing the reefs to be rebuilt much faster than they would if the oyster population was to proceed naturally.

The New York Harbor is not the only place where such initiatives are being taken. Such efforts began in Chesapeake Bay in the 1990s and are being seriously contemplated off of Cape Cod. Polluted waters are a prolific problem and using natural filters like oysters is one of many steps that can be taken to address the issue. The Billion Oyster Project has partnered with dozens of public schools around New York City to foster a passion for environmental protection in children so such efforts can continue.

This project has received millions of dollars from the National Science Foundation and the Department of Housing and Urban Development's Disaster Recovery Fund. Beyond cleaning the waters, the reefs used to act as breakwaters, helping to protect coastlines from rough waves caused by major storms like Superstorm Sandy. Breakwaters, which can be natural or artificial, exist on the seafloor, intercepting underwater currents to minimize the energy of waves on the surface. Recently, however, evidence has shown that artificial breakwaters can cause litter accumulation that threatens wildlife. As such, natural breakwaters, like the ones whose rebuilding efforts are being jump started by the Billion Oyster Project, can be more effective as a whole. While climate change is a huge issue that needs to be addressed, rebuilding reefs that used to canvas the seafloor is one step that can be taken improve water quality and mitigate the effects of progressively worsening storms.

A view of Governor's Island, out of which the Billion Oyster Project is run, from Brooklyn Heights.

PHOTO BY SINAIA KEITH LANG

Science of the Total Environment (2004). DOI: 10.1016/S0048-9697(03)00437-6
PLOS ONE (2011). DOI: 10.1371/journal.pone.0022396
Environmental Pollution (2016). DOI: 10.1016/j.envpol.2016.04.058

THE HORN HANG-UP

Are biosynthetic horns the solution to saving the rhinoceros?

WRITTEN AND DESIGNED BY LILLIE HOFFART, ENVIRONMENTAL SCIENCE, 2022

In **March 2017**, poachers broke into Thoiry Zoo outside Paris, killed a white rhino named Vince, and sawed off his horn to sell on the black market. This is one of many examples of the threat rhinoceroses face. In South Africa, home to the world's largest white rhino population, over 1000 individuals are poached a year since 2013, according to the Environmental Investigation Agency, a non-governmental organization that campaigns against environmental abuses. Poachers risk capture and sometimes their lives — such as in the case of Kenya's Borana nature reserve, where armed rangers will use lethal force to protect rhinos — to make a profit. One horn can fetch thousands of dollars per pound.

Black, greater one-horned, Javan, and Sumatran rhinos are all protected under CITES Appendix I, which outlaws all trade of the species. The white rhino is near-threatened and is listed under Appendix II, which allows controlled trade.

This status led to China's announcement last fall that it was lifting the ban on trade of captive rhinoceroses and tigers for use in traditional medicine. Amid protests from wildlife conservation groups fearing repercussions for wild populations, it was soon withdrawn; on Nov. 12, 2018, Chinese State Council Executive Deputy Secretary-General Ding Xuedong stated the legalization was to be "postponed after study," and China would continue to "focus on addressing the illegal trade of rhinos, tigers and their byproducts," according to state media.

Referenced in traditional Chinese texts, such as the 16th century Pen Ts'ao Kang Mu, a horn can be boiled or shaved to treat ailments including fever, rheumatism, gout, snakebites, hallucinations, typhoid, and headaches. However, not all rhino horns are used for traditional cures; studies have shown this is a myth perpetuated by Western culture. According to a media analysis comparing Chinese and Western newspapers, mentions of rhino horns for medicinal use showed up 84 percent of the time in Western media compared to 29 percent of the time in Chinese media. Instead, Chinese media reported on horns for their artistic and collectable value 75 percent of the time.

The rhinoceros horn is prized by artisans because of its density. They are solid, while other horns, like those from a cow, are hollow. Wealthy collectors price large carvings because of their rarity and display them as a status symbol or give them as extravagant gifts, according to the media study.

Whether it is used as a traditional medicinal panacea or as a medium for artisians, the demand for horns has fueled the black market trade. In response, a handful of biosynthetic startups are engineering synthetic horns as an alternative for consumers. Pembient, a startup specializing in the creation of synthetic horns, announces its "vision of a world without wildlife poaching" on its website and intends to flood the market with its product to decrease poaching.

Pembient creates biosynthetic horns by culturing yeast cells to produce keratin, the protein found in horns. Rhinoceros cells are duplicated and added to the synthetic keratin so it is genetically similar to the real thing. This serves as the "ink" for printing. Pembient is still in the prototyping phase, but expects its first pilot run in 2022. According to its website, Pembient has already "received interest from artisans, carvers and industrial designers."

Although it may seem like the perfect fix to preserve culture, keep consumers happy, and protect an animal, this solution has problems. In June 2015, the conservation groups Save the Rhino International and the International Rhino Fund published a joint statement on their websites announcing they are "opposed to the development, marketing and sale of synthetic rhino horn." These groups fear introducing synthetic horns will unintentionally hinder wild populations.

Among a list of thirteen points opposing the creation of synthetic horns are concerns that it would "give credence to the notion that rhino horn has medicinal value" — which has no scientific backing. They also worry the introduction of the synthetic horn would remove the current stigma, cause problems for law enforcement tasked with determining differences between real and synthetic products, or kindle a larger market base.

For example, a 2017 economic study found auction records "showed a significant positive correlation between the volume of rhino horn auctioned in China and the number of rhinos poached in South Africa." This means the increased availability of horns boosts poaching.

> **"[There's a] significant positive correlation between the volume of rhino horn auctioned in China and the number of rhinos poached in South Africa."**
>
> Ecological Economics 2017

Despite these arguments, Pembient sees potential for allowing countries to embrace their cultural heritage. Still, the question remains whether biosynthetic horns can be a viable solution to protect wild rhinos.

Biological Conservation (2016). DOI: 10.1016/j.biocon.2016.08.001

Ecological Economics (2017). DOI: 10.1016/j.ecolecon.2017.06.003

The IUCN Red List of Threatened Species (2012). 10.2305/IUCN.UK.2012.RLTS.T4185A16980466.en.

CRISPR BRINGS SYNTHETIC, DE-EXTINCT SPECIES WITHIN THE REALM OF POSSIBILITY

BY ROXANNE LEE, ENVIRONMENTAL SCIENCE & POLICY, 2019

For years, the concept of resurrecting extinct species through scientific means was restricted to the realm of science fiction. However, the cloning of the first mammal in 1996 broke that barrier, and modern technologies like CRISPR-Cas9 are opening possibilities for even more radical cloning and de-extinction endeavors.

CRISPR-Cas9, a gene editing technology that allows for DNA to be altered effectively and cheaply, has made headlines in recent years for its potential utilization in de-extinction. It can allow for the replacement of loci in a genome with copies from other genes, thus facilitating the transfer of physical traits. It is technically cloning, but rather than creating a genetically perfect copy of an animal by using a sample of DNA, CRISPR allows for a creation of a chimera that may outwardly express traits of the extinct animal.

Among the organizations implementing the tool is conservation group Revive & Restore, who are using the technique to attempt to bring back the passenger pigeon. The passenger pigeon was once the most numerous bird in North America, with some flocks numbering 3 billion. Overhunting by humans and habitat loss led to their extinction in 1914.

Revive & Restore's program aims to alter a captive population of rock and band-tailed pigeons, with pieces of passenger pigeon DNA. They will then alter the flock's offspring with even more pieces of DNA and have them breed through multiple generations until the flock exhibits enough passenger pigeon traits to resemble the extinct birds.

However, resurrecting species through such a method leads to some concerns. Where would they live, if their original ecologies have been altered or destroyed by humans? Would an artificially created species still be due the protections and rights of a natural species? Is there a difference between resurrecting to refill an essential ecological niche as opposed to resurrecting purely for aesthetic or cultural value?

The quandaries of synthetic species will only become more pressing with time. With such forces as urbanization and climate change placing increasing pressures on natural systems, more species are being threatened with extinction. The question of whether cloning is the best way to save a species, or resurrect it if it's already extinct, will keep coming up whether we have an answer ready or not.

Genome Biology (2015). DOI:10.1186/s13059-015-0800-4

The revival of aesthetic evolution

BY CONRAD CASSIRER, PHYSICS, 2021

It is hard to believe that the extravagant tail feathers of a peacock are at all relevant to its ability to survive, let alone fly. However, most evolutionary biologists today adhere to an adaptationist understanding of evolution and will tell you that such features must indicate something about the peacock's overall fitness to its environment.

Richard O. Prum, an ornithologist at Yale University, wholeheartedly dismisses this notion. In his book, The Evolution of Beauty, Prum uses his expansive knowledge of bird displays and behavior to argue in favor of an essentially forgotten theory of Charles Darwin.

Contrary to popular belief, Darwin did not believe in a purely functional explanation of evolution. In his book, The Descent of Man, Darwin argued that, similar to humans, some animals have aesthetic preferences which partially determine how they choose their mates, through sexual selection. It follows that beauty itself evolves in response to a collection of individual tastes, independent of any function.

Prum argues that acknowledging Darwin's theory of aesthetic evolution, alongside the paradigm of evolution through natural selection, provides us with a stronger explanation of many outlandish display phenomena, especially in avian biology.

According to adaptationists, ornaments serve as fitness indicators to potential mates; they evolved to convey the overall condition and health of the animal during courtship, similar to if humans displayed their Fitbit statistics and medical records on their skin while going on dates.

Despite acknowledging its widespread acceptance, Prum insists that the adaptationist view is built upon dubious reasoning and lacks sufficient evidence. He believes that sexual selection provides a far more complete and flexible explanation of how display features could have evolved. Instead of strictly adhering to the principle of natural selection, all species lie on an evolutionary spectrum with aesthetic traits on one end and functional traits at the other. For example, rhinoceroses are heavily clad in drab armor to help them survive, thus lying on the functional end of the spectrum, whereas the Great Argus Pheasant exhibits a dazzling mating display to the detriment of its flying abilities, placing it on the aesthetic end of the spectrum.

Prum's arguments have received some criticism from members of the adaptationist school of thought and should be examined with healthy skepticism. That said, he has successfully rekindled the discussion of whether or not sexual selection is a distinct evolutionary force, and pointed to many potential areas of research to explore.

DESIGN BY LILLIE HOFFART, ENVIRONMENTAL SCIENCE, 2022
PHOTOS BY PIXABAY AND SIVA PRASAD

ROSES ARE BLUE, VIOLETS ARE RED: CREATING FLOWERS OF DIFFERENT COLORS

BY PAULA HORNSTEIN, BIOCHEMISTRY, 2020

DESIGN BY NEELOY BOSE, BIOENGINEERING, 2022

Pink roses convey admiration and grace, peach roses gratefulness, yellow roses friendship, and red roses love. But, blue roses? As the newest color rose to join the reigns of flower royalty, the symbolism is a bit more complex, as is the science behind its creation.

The concept of the "blue rose" has been around for centuries, although it has never existed in nature. In literature and art, the blue rose has symbolized the quest for the unattainable, the strength in human ambition, and immortality. Culturally, it was once considered a rose of royalty, attainable only by those closest to the heavens.

An early literary description of a blue rose is from an Arabic manuscript created circa 1270 A.D., entitled Kitāb al-malāḥah fī 'ilm al-filāḥah /, in which the dyeing of a blue rose is described. According to this agricultural manuscript, it was a common practice in Asia to dye the bark of the rose's roots with natural pigments.

A modern but similar method of creating blue roses is to place young roses with strategically cut stems into colored water and allow two days for absorption. Although the roses are beautiful, these methods of creating synthetic blue roses are unsustainable, as they do not allow for a lineage of blue roses.

As of late 2018, however, creating a lineage of natural blue roses is no longer an impossible feat. The American Chemical Society Synthetic Biology Journal published an article entitled "Cloning and Expression of a Nonribosomal Peptide Synthetase to Generate Blue Rose," which details how scientists were able to generate proof of concept for the creation of an unnaturally colored rose that is able to reproduce.

In 2004, Australian and Japanese industry researchers jointly attempted to genetically engineer a blue rose by using RNA interference (RNAi) technology to depress production of the color-causing pigment DFR and inserting a gene for the blue pigment delphinidin that was resistant to interference. They were unsuccessful in completely knocking out the DFR gene, resulting in the creation of a rose that was more lavender in color. With this study in mind, the scientists involved in the 2018 publication attempted to look deeper into all factors affecting pigmentation.

In creating the blue rose in 2018, the synthetic biologists from Tianjin University and the University of Chinese Academy of Sciences sought to combine their knowledge of the molecular processes involved with petal pigmentation to modern genetic technology. Specifically, the scientists sought to manipulate and employ the enzymes involved in pigmentation in a white rose. The enzyme that they focused on is a nonribosomal peptide synthetase (NRPS), which, when functional, converts the amino acid glutamine into a blue pigment, indigoidine. The scientists were able to activate this enzyme by first activating the gene Sfp, which would then activate the gene IdgS, which would lead to the production of the NRPS. This was done through petal injection by agro-infiltration, which allows certain genes to be expressed within a region around the injection spot.

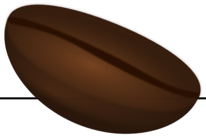
This process is not as simple as activating a few genes. Many factors can create unintended effects on the petal color. Methylation, for instance, causes some pigment-related genes to be activated and deactivated, causing undesired reddening or yellowing of the petals. The pH of the vacuole where the flavonoids—a class of plant pigments—are located is also integral to the colors of the petals; a neutral or weakly acidic pH causes activation of the blue pigments, while acidic pH activates the red pigments. Co-pigments to the desired pigments are stacked in a way in the vacuole so that they are often activated with the flavonoids. Lastly, the presence of metal ions can result in complexes that affect the pigment production. Amidst this complexity, a blue-tinted rose was created, with the color most apparent at the site of petal injection.

The conception of a blue rose provides hope for the future of floriculture. The methods outlined in the publication provide future researchers with knowledge of many of the factors involved in petal pigmentation, which can be further studied and potentially manipulated to create flowers of any desired color.

The question remains, what would this new, blue rose signify? Formerly symbolic of an unattainable dream, the existence of the blue rose can symbolize the progression and advancements of technology from what was previously thought to be impossible. It is clear that the development of the blue rose is significant to our understanding of nature, regardless of the meaning behind a gift of blue roses to a friend or loved one.

ACS Synthetic Biology (2018). DOI: 10.1021/acssynbio.8b00187

PHOTO BY SAM KLEIN



CAN ESPRESSO SHOTS REPLACE INSULIN SHOTS?

BY KAELEN ENCARNACION, BIOLOGY & ENGLISH, 2021

DESIGN BY KATIE GREEN, BIOENGINEERING, 2021

Maybe you've heard the saying: "A coffee a day keeps the doctor away?" While not quite an adage, more and more research has come out citing coffee for its great health benefits. Increased coffee intake is correlated with a lower risk of developing or worsening the effects of diseases such as Alzheimer's, Parkinson's, multiple sclerosis, cardiovascular disease, and certain types of cancer. In particular, these health benefits are often enhanced by caffeine, the psychoactive stimulant that typically gives coffee its "kick" by blocking the inhibitory neurotransmitter adenosine. Controlled studies in humans have shown that caffeine consumption can improve various brain functions such as memory, energy levels, and mood. Additionally, a variety of studies have found a significant connection between coffee drinkers and having a greatly decreased risk in developing type-2 diabetes. Now, scientists are looking for potential ways to harness the caffeine content in coffee in order to help patients already suffering from diabetes.

> "The blood-sugar levels in these animals could be regulated simply by the type of beverage that was added to their meals."

Diabetes mellitus, more commonly known as diabetes, is a group of diseases that interfere with the body's ability to produce insulin—a hormone released by the pancreas that signals other cells to take up the glucose in the bloodstream and use it for energy. In type-2 diabetes, the body cells develop a resistance against insulin and the pancreas is unable to compensate for this. As a result, the body is unable to absorb the excess sugar in the blood, leading to symptoms such as fatigue, extreme hunger or thirst, blurry vision, frequent urination, and cuts or sores that do not heal properly. As of yet, diabetes still has no cure and affects over 400 million people worldwide.

In a 2018 research study published in Nature Communications, the Swiss Federal Institute of Technology in Zurich looked to harness caffeine consumption to combat the insulin-production challenges faced by patients with type-2 diabetes. Researchers have genetically engineered human embryonic kidney cells that promote the production of insulin when exposed to caffeine, providing a promising therapeutic approach for those already suffering from type-2 diabetes.

In order to do this, the researchers created a receptor in the kidney cells that becomes activated when it senses caffeine coursing through the bloodstream, which they referred to as caffeine-stimulated advanced regulators, or C-STAR. When these receptors turn on, the cell responds by producing a synthetic version of human glucagon-like peptide 1 (GLP-1), a protein that promotes the production and release of insulin. To test out the efficacy of C-STAR, the researchers injected implants containing hundreds of these "designer" cells into two mouse models with type-2 diabetes. Then, they exposed the mice to drinks that had varying levels of caffeine, ranging from chocolate milk and herbal tea to Red Bull, cola, and Starbucks coffee.

The results were much more fine-tuned than expected. While drinks with little to no caffeine content such as chocolate milk and herbal tea had no effect, all of the caffeinated drinks led to an increase in GLP-1 levels. Not only that, but the increase was dependent on the amount of caffeine in each drink, showing that C-STAR doesn't simply act as an on-and-off switch for insulin expression, but can rather adjust the levels according to the concentration of caffeine detected in the bloodstream. In other words, the blood-sugar levels in these animals could be regulated simply by the type of beverage that was added to their meals.

While the results of this study may sound promising for those with diabetes, this technology is still in its early stages of development and will be unlikely to undergo human trials for another decade or so. However, if proven to be safe and effective, these C-STAR implants could possibly replace the regular insulin injections required by diabetics. As Martin Fussenegger, principle investigator of the research, told The Guardian, "You could have your normal life back. The implant could last for six months to a year before it would need to be replaced."

So, while taking shots of caffeine might not be a reasonable option for everyone with diabetes, this type of research could one day give some control back to those who are able to integrate the treatment into their everyday lives, allowing them to adjust their own blood-sugar levels merely by having a coffee or tea along with their meal. A coffee a day to keep the doctor away could actually be a reality someday!

PHOTOS BY FREESTOCKPHOTOS.BIZ AND PIXABAY

BITE-SIZED BRAINS

"...CEREBRAL ORGANOIDS, TERMED MINI BRAINS, NOW REACH THE COMPLEXITY OF THAT OF A FEW-MONTH-OLD FETUS..."

BY KRISTINA KLOSOWSKI, BEHAVIORAL NEUROSCIENCE, 2021
DESIGN BY TRAM ANH NGUYEN, BIOLOGY, 2022

It's the stereotypical image of a mad scientist's laboratory: miniature human organs growing in petri dishes. Engineers have brought in-vitro research to a 3D level by growing both pluripotent and adult stem cells into complex structures called organoids. These micro-scale models of human organs, which can be anything from retinas to kidneys, have allowed scientists to more accurately create disease models and test molecules on human pathology—which is a significant shortcoming of in-vivo techniques. However, such a substantial advancement in an already controversial field of study brings about not only biological challenges, but philosophical ones as well.

According to public opinion polls done by Gallup, a majority of Americans now think that stem-cell research is morally permissible. However, cerebral organoids, termed "mini-brains", now reach the complexity of that of a few-month-old fetus'. Among a number of ethical concerns, this raises an entirely new question: do these structures have the potential for consciousness? Scientists would probably agree that they have not reached this threshold capability yet, but it is possible that we are close. Current diagnostic techniques such as perturbational complexity index—which is used to asses sentience in brain-injured, unresponsive patients—could be used to address similar questions in cerebral organoids.

To be clear, cerebral organoids are not a complete miniature replica of the human brain. They do not possess even the simplest complete synaptic circuits essential for communication with other parts of a brain. And the creation of neurons that can generate action potentials is not new technology—this was already possible in 2D cell cultures.

So what is it that sets these organoids apart? According to a 2018 study published in the Journal of Medical Ethics, the fact that they already possess some structural features of mature neurons suggests that they may have the ability to form neural networks than can "support self-organized patterns of activity." Essentially, this is significant enough that it may be possible to stimulate these organoids to prompt simple sensations.

Arguably, one of the most fundamental sensations we experience as living beings is our ability to feel pain. Our response to painful stimuli is reflexive, and is often exhibited even when we are otherwise incapacitated. The most basic criteria of sentience—the ability to sense one's surroundings—all include a minimum level of consciousness and the ability to perceive painful stimuli. The challenge in determining sentience of an organoid is, in some ways, similar to the challenges of determining consciousness in humans that are unresponsive—they have no way of communicating with us.

Interestingly, there is a method to quantify levels of consciousness in those who are unresponsive. This method uses a combination transcranial magnetic stimulation (TMS), a non-invasive procedure that stimulates neurons using a magnetic field, and electroencephalography (EEG), a technique that records the electrical impulses of neurons. Essentially, TMS is used to stimulate the brain cells of an unresponsive person while EEG is employed to measure the electrophysiological response. Scientists will read the results of this technique to determine whether the recorded neural activity matches up with the level and types of activity required to indicate consciousness. While not perfect, this may also allow a primitive assessment of sentience in cerebral organoids.

The greatest debacle is the moral and ethical debate that would ensue if any level of sentience were to be detected. Most would agree that this would differentiate between organoids and the stem-cell research done up until this point, and at least call for a different set of guidelines to be discussed. Though these mini-brains are a feat of engineering and a huge progression in biomedical research, they require a careful analysis of whether technology has once again surpassed its ethical considerations.

Journal of Medical Ethics (2018) DOI:10.1136/medethics -2017-104555
Science Translational Medicine (2013) DOI: 10.1126/scitranslmed.3006294

IMAGE BY THE NOUN PROJECT

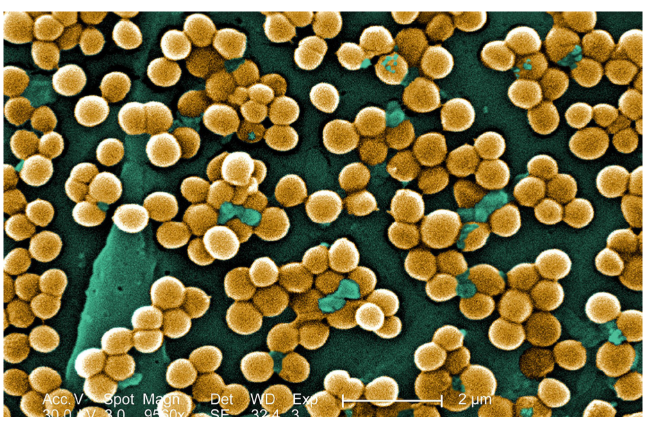
SYNTHETIC MOLECULES

FIGHTING ANTIBIOTIC RESISTANCE

BY RACHEL GRIEP, BIOLOGY & PSYCHOLOGY, 2022
DESIGN BY TRAM ANH NGUYEN, BIOLOGY, 2022

Since the discovery of penicillin by Alexander Fleming in 1928, antibiotics have become an integral part of modern healthcare. Since then, antibiotics have become commonplace. Disease causing microbes are increasingly becoming antibiotic resistant. According to the World Health Organization, the issue of antibiotic resistance is one of the biggest threats to global health, with common diseases such as pneumonia, tuberculosis, gonorrhea, and salmonellosis, becoming more difficult to treat. By 2050, as many as 10 million people may die per year due to infections by antibiotic-resistant microbes. Researchers are looking for a biological solution.

One team of researchers at IBM is working on the issue of antibiotic resistance by focusing on creating antibiotics that are derived from synthetic rather than living sources. The researchers successfully created a large synthetic polymer that mimics the defense mechanisms of the human body. The polymer mimics the antimicrobial peptides that are secreted by the body as a part of the innate immune system when foreign microbes are detected. The synthetic molecule works in almost the same way as the antimicrobial peptides do; it breaks down the protective cell membranes of the microbes, splitting them open. However, instead of causing the microbes to lyse, which releases toxins into the bloodstream, the synthetic molecule causes the microbes to fold in on themselves, preventing the spread of toxins.



Researchers at IMB are working on creating antibiotics that are derived from synthethic molecules to fight antibiotic resistant bacteria strains, one of which is MRSA.

Currently, this synthetic molecule fights five of the most common strains of antibiotic-resistant infections. In addition to being an effective killer of disease-causing bacteria, this synthetic molecule helps to reduce antibiotic resistance through electrostatic interactions. The positive polymer is attracted to multiple negative sites along the invading microbial species so that even as the microbes evolve and become antibiotic-resistant the synthetic polymer will still be attracted to negative sites and will still function properly.

The researchers at IBM improved upon past models with their new synthetic molecule. It is more biodegradable and causes less damage to internal organs, specifically the liver, than drugs currently used to kill highly resistant strains of bacteria Currently, the drug is still being tested on mice. The next step, assuming success in trials with mice, would be for IBM to seek both a medical services partner and approval for human trials. There is a long way to go before this drug can be prescribed to patients, but there is a direction and a desire.

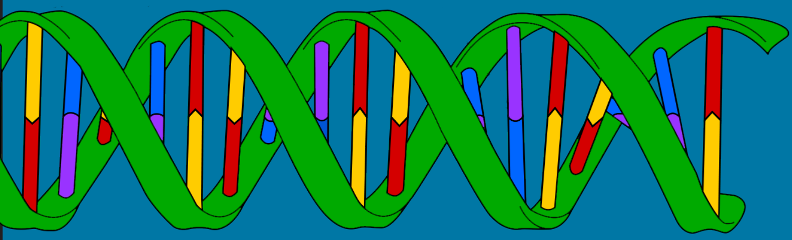
Nature Communications (2018) DOI: 10.1038/s41467-018-03325-6

IMAGE BY GOOGLE CREATIVE COMMONS

Digital data to DNA:

Mimicking biological material to advance informatics

BY HEATHER OFFERMANN, BEHAVIORAL NEUROSCIENCE, 2019
DESIGN BY IAN PROULX, BIOENGINEERING, 2022



The amount of digital information we have today is inconceivable. Collectively, every computer, phone, and data center takes up trillions of gigabytes of storage in the forms of images, movies, documents, and more. As the digital universe expands each minute, we are in dire need of creating a new way to store data. Our current method of saving information, typically on magnetic tape, is inexpensive yet extremely taxing on physical space and energy consumption. It is estimated that data centers account for nearly two percent of the total electricity usage in the United States. In hopes of resolving this information overload, researchers from the Molecular Information Systems Lab (MISL) at the University of Washington took inspiration from our natural hereditary material.

Deoxyribonucleic acid (DNA), one of the most famous molecules on earth, contains all of the information required to build an organism. This magnificent form of storage can compact information many millions of times more densely than our existing hard drives. The four building blocks of DNA—adenine, guanine, cytosine, and thymine—are strung along in a multitude of combinations that code for the synthesis of proteins. With this basic knowledge, it was proposed that perhaps any non-biological information could be stored within the sequences of lab-made DNA through binary code translation. Computers use long chains of zeros and ones to process and store digital information. This binary code can be translated into the simple four-letter alphabet of DNA—A, G, C, and T—by correlating 00 to A, 01 to G, 10 to C, and 11 to T.

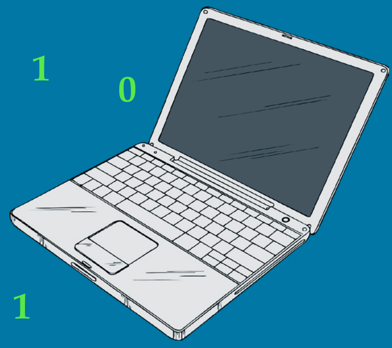
This translation is no new concept—scientists have been experimenting with storing digital data in DNA since 2012. However, at this point in time, synthetic DNA storage is only useful for archival purposes. In other words, DNA can be used as a way to store and later access large bouts of information, but it has yet to be turned into an effective system for randomly retrieving data, similar to an internet search that can be used in real time to sort through all information for a specific search term. The researchers at the MISL are working on developing a "complete system architecture for DNA-backed archival storage, with support for random access and encoding schemes…" by asking the public for their help in providing data for the research. In their latest project, #MemoriesInDNA, the MISL is looking to collect 10,000 original photos from around the world, sourced from online submissions. This dataset will lead to the creation of compacted DNA storage, preserving those images for thousands of years.

In an interview with the University of Washington News, the team members discussed their anticipated challenges in performing data processing within the DNA, without having to convert the images back to their original form. Like a Google search, they want to be able to find all photographs that, for example, have a red car in them, or a face of a particular person. To obtain this level of retrieval, DNA processing must rely on the basic fact that certain DNA bases bind to each other—A to T, and C to G. By introducing strips of DNA that "contain a coded 'query'– essentially a string of complementary DNA that causes all photographs with a red car or certain facial features or whatever meets the query that bind to it," a magnet can be used to pull out all similar images that have stuck to it. This method of retrieval is still in the works, but competition will ultimately transform the way we not only store information, but have enhanced access to more international data.

> "[DNA] can compact information many millions of times more densely than our existing hard drives."

Through public participation, the future of storage can be advanced to become incredibly affordable and efficient. On their website, memoriesindna.com, they ask willing participants, "What do you want to remember forever?" These images can last thousands of years; just think about the possibilities of future generations accessing the creations of today. The digital universe in synthetic DNA certainly has potential; a concept that will hopefully lead to better environmental control and inspire the creation of larger, more complex information sharing.

PHOTOS BY WIKIMEDIA COMMONS AND PIXABAY



WHEN MAN BECOMES MACHINE

BY ALEXANDRA JACULLO, BEHAVIORAL NEUROSCIENCE, 2021

DESIGN BY JARED BRAUSER, MECHANICAL ENGINEERING, 2023

The brain-machine interface is one of the most intriguing yet enigmatic research endeavors being tackled today. At first glance, it can seem like an overwhelming concept; a seemingly distant probability of a future reality. The truth is, people are already living in an age where the lines between humans and artificial intelligence are blurred.

Neuroprosthetics and neural implants are extremely significant areas of focus for many experts in biotechnology. Many advancements have been made in the field, such as widespread access to devices like cochlear implants for people with hearing loss not involving damage to the auditory nerve. The fondly-named bionic eye has also demonstrated success in replacing a damaged eye and restoring vision.

Perhaps one of the most popular neural implant technologies in use today is dedicated to alleviating the motor deficits of Parkinson's disease. Individuals with this disease commonly experience abnormalities in motor control such as tremors, rigidity, and slow movements that make daily life and activities difficult. In pursuit of a treatment for Parkinson's, scientists are using neuroprosthetics to deliver deep brain stimulation (DBS). It works using electrodes implanted inside the brain in particular areas involved in the initiation and control of movement. While this strategy does not target the underlying disease itself or slow its progression, it has been shown to significantly improve motor symptoms and increase quality of life for Parkinson's patients.

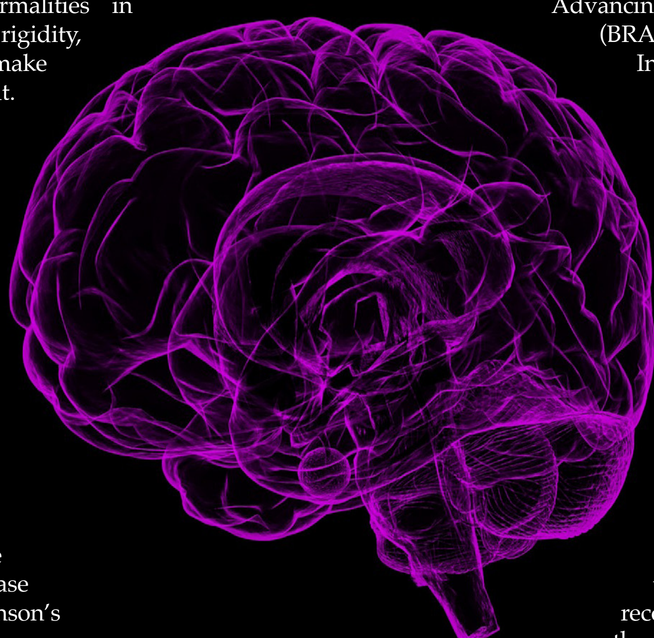


PHOTO BY PIXABAY

Vanderbilt University Medical Center (VUMC) is a leader in the advancement of DBS procedures, having reached the milestone of 1,000 patients treated as of 2016. Dr. Peter Konrad, Professor of Neurological Surgery at VUMC, praised the program—of which he is an integral member—in an article from the center's news outlet, "We have probably the largest number of patients that have come through." A member of Konrad's team, neurologist Dr. Fenna Phibbs, also emphasized the importance of an interdisciplinary team dynamic: "It is not one-person driven. It is not one-specialty driven. What drives us is giving the best therapy for the patient."

The future of neuroprosthetics is full of promise, but it is also riddled with challenges as well. Researchers studying Parkinson's acknowledge that there needs to be a safer, more reliable way of inserting electrodes and other neural probes into the brain that does not involve invasive surgical implantation. Similarly, many of these neural devices are powered by batteries that have a shelf life. Then, surgery is required to replace the battery source, and for many that could mean countless subsequent surgical procedures over their lifetime.

Part of this research focuses on the development of biologically safe and effective materials to create devices to live inside the human body. These materials need to be non-toxic and also biocompatible so they can function symbiotically and prevent immune system rejection of the foreign material.

Researchers are also channeling their efforts into creating prosthetic devices that are even smaller in size with greater power and capabilities. An integral aspect of neuroprosthetic development is allowing the implant to interact with the brain in a more compatible way. Recently, supported by the National Institutes of Health's Brain Research through Advancing Innovative Technologies (BRAIN) Initiative and the National Institute of Neurological Disorders and Stroke (NINDS), a team of researchers and doctors documented preliminary clinical efficacy of a deep brain stimulation implant for Parkinson's disease patients that can simultaneously monitor and modulate brain activity. By monitoring the brain's own electrical output, the device can more effectively modify its performance to only stimulate the brain when necessary depending on the feedback received from recording electrodes. This adaptive method allowed for the neural implant to conserve battery energy because it turned off when it did not need to stimulate the brain. It also prevented the patient from experiencing unintended effects of the constant stimulation.

Breakthroughs like this indicate just how efficient neuroprosthetics could become and how much improvement is required to get there. Soon there may be prosthetics specifically for the optic nerve or visual cortex as a way of restoring sight for those who are visually impaired. Limbic system implants may be able to help victims of post-traumatic stress disorder recover by interfering with traumatic memories. Epilepsy, Alzheimer's disease, mental illness, and forms of brain injury may all one day be easily treated with neuroprosthetic technology. The future applications of implantable prosthetic devices for the brain are seeming boundless, not only for the treatment of serious neural conditions, but eventually for the enhancement of common brain functions.

Journal of Neural Engineering (2018) DOI: 10.1088/1741-2552/aabc9b
Journal of Long-Term Effects of Medical Implants (2009) DOI:10.1615/JLongTermEffMedImplants.v19.i2.40

THE FUTURE OF BIOLOGICAL ARCHITECTURE: A HOME RENOVATION GUIDE

BY ANNABELLE MATHERS, CIVIL ENGINEERING, 2022

DESIGN BY YECHAN YANG, PSYCHOLOGY, 2022

A recent attraction has formed around the televised renovation of houses, centering on the idea that people must "bring life" back into outdated structures. What if there was a different way to attribute a lifelike quality to architecture that would actively improve the condition of those very inhabitants? The unlikely union of architecture and synthetic biology uses nature's microscopic world to supplement the static materials of an artificial world. Driven by a global need for natural resources, eco-friendly efficiency, and structural resiliency, architects and scientists are collaboratively developing buildings that contain self-sustaining, purifying, and protective mechanisms.

Biologically-inspired architecture has at least two main facets that are crucially linked: mimicry of nature through manmade materials, and the actual harnessing of living organisms within construction materials. In particular, recent advances in synthetic technology have given way to burgeoning studies on bacteria-based materials, electronic "eSkin," and microbial reactor systems. Each of these technologies seeks to respectively apply microscopic mechanisms to the macroscopic scale of foundations, exteriors, and interiors of responsive architecture.

BIO-CONCRETE

Already existent in the commercial market, bio-concrete is a combination of bacteria and biofilm manipulations that cause biomineralization—a process where bacteria respond to environmental changes by producing mineral crystals. Carefully cultured biofilms foster bacteria in a protective environment, optimizing inter-bacterial communication. Such biofilms yield an extracellular matrix or a conglomeration of nucleic acids, proteins and exopolysaccharides. Manipulation of these organic matrices, with which the bacteria interact, creates theoretically limitless ways to influence the behavior of bacteria.

Thus, synthetically-induced biomineralization becomes relevant. When combined with pre-existing nutrients in concrete, and faced with eventual nutrient depletion from concrete erosion, bacteria can be compelled to transform nearby carbon dioxide and calcium into a solid, calcium-carbonate precipitate. In other words, foundational cracks can be self-healed by precipitous reactions, while carbon dioxide concentrations in the air can be decreased. The high variability of bacterial behavior enables buildings to essentially acquire an internal metabolism that responds dynamically to stress.

ESKIN

When addressing environmental stress, however, the most intimate inspiration for researchers is the human response system itself. Consequently, Jenny Sabin of Cornell University is part of an effort to develop eSkin, a glass-encased mimicry of human cellular responses designed for the surfaces of buildings. Ideally, building exteriors, strategically layered with a combination of sensors and nanoparticles (e.g. silica), will respond efficiently to fluctuations in temperature and solar energy.

In creating these nanosystems, researchers use additional sensors and imagers to track how human smooth muscle cells manipulate their own characteristics and environment when stimulated. Polarity, opacity, organization, and color are a few of the cellular manipulations, which are then behaviorally mimicked by nanoparticles. Stimuli translate to specific voltages passed along the eSkin, signaling the nanoparticles to react accordingly. These compact nanosystems harbor a potential substitute for traditionally protective glazes on glass building exteriors. As with bacteria, the variability of adaptive nanoparticle behavior enables more dynamic and resilient architecture, with respect to changes in climate and solar energy, than a static glaze material.

BIOREACTORS

Focusing more on interior architecture, aquarium-esque walls made of microbial systems may one day metabolically maintain household conditions. Rachel Armstrong of Newcastle University, along with many other key experts, is part of Living Architecture, a group that prototypes these systems. Three types of bioreactors, separated by water and semi-permeable membranes, constitute a wall: bacterial, algal, and synthetic. Bacteria collectively act as an anaerobic fuel cell yielding electricity and clean water. Algal photosynthesis produces biomass, known as organic fuel commonly harnessed for electricity, to also fertilize the self-sustaining system.

With great anticipation of the material possibilities, experts continue to genetically modify microbial processors in the third bioreactor, which produces plant-based materials and biomass for fuel. Nutrients in the circulating grey water, or home appliance-used water, promote overall microbial growth. Evidently, an integral function to the reactors is energy-efficiency and water treatment, but a more philosophical view emphasizes nature as a dynamic partner in people's lives. Bioreactors could more intuitively and specifically address constant needs, especially if linked with additional sensors, like eSkin. These independent systems could, in fact, allow people to become more self-sufficient, within the comfort of their own home.

It is this idea, of independent flexibility, that belongs to both scientific and artistic design. Perhaps, the renovation race to develop improved, artificial building systems is flawed in its basic premise; it does not consider the natural mechanisms that lay just outside the front door. Bio-concrete, eSkin and bioreactors may someday be the architectural liaisons between people and a sustainable future.

Microbial Biotechnology (2017). DOI: 10.111/1751-7915.12833

PHOTO AND GRAPHIC BY PIXABAY

Weird flex: Field-responsive mechanical metamaterials

WRITTEN AND DESIGNED BY JENNIFER GARLAND, APPLIED PHYSICS & MATHEMATICS, 2021

Many of today's synthetic materials were inspired by nature. Jeffrey Grossman, a materials science and engineering professor at the Massachusetts Institute of Technology (MIT), has said that "nature is a polymer engineer gone wild." However, even with all of the blueprints provided by nature, there is still demand for more efficient performance and increasingly technical applications. The field of metamaterials arose because scientists wanted to create materials with properties outside of nature.

Mechanical metamaterials, just one of many types, are structurally tuned to respond to forces in unconventional ways. This may mean that a material widens in one direction while being stretched in the perpendicular, the opposite of what a rubber band does, or that a solid responds to stress like a fluid: incompressible but not stiff. Recently, a collaboration led by engineer Julie A. Jackson at Lawrence Livermore National Laboratory (LLNL) introduced a new class of materials called field-responsive mechanical metamaterials (FRMMs) whose mechanical properties can be controlled by applying a magnetic field.

> "The structure of the material remained the same, but its mechanical ability was altered by the field."

The team first 3D-printed hollow polymer tubes that serve as the structural components of lattice shapes called cuboctahedrons. Then, the hollow lattices were injected with magnetorheological fluid, which is made up of magnetic microparticles suspended in liquid. This fluid acts like a normal liquid until a magnetic field is applied and the particles link up and align with the field, resulting in a large increase in viscosity. The aligned fluid looks similar to the spiky array of magnetized ferrofluid common in science museums, but the particles in ferrofluid are on the nanometer scale, much smaller than the microparticles. A photo of a cuboctahedron half-filled with magnetorheological fluid was featured on the cover of the December 2018 issue of Science Advances.

PHOTO BY WIKIPEDIA COMMONS

To demonstrate the effects of the increase in stiffness, the cuboctahedrons were placed under a load. Under a large applied magnetic field, the lattices supported the load, but as the field decreased, the structures began to lose stiffness and collapse. This behavior is significant because the structure of the material remained the same, but its mechanical ability was altered by the field.

The development of FRMMs has been largely enabled by manufacturing innovations like 3D printing, especially a method called large area projection microstereolithography (LAPμSL) that was invented at LLNL. The researchers there will continue to optimize construction, ideally figuring out a way to integrate the magnetorheological fluid with the polymer lattice instead of having to manually inject it.

The level of control possible over these field-responsive mechanical metamaterials sets them apart from other mechanical metamaterials. The stiffness response in the LNLL experiments was very quick, less than a second, and that behavior is reversible without damage. Instead of just creating a material with useful set properties, FRMMs add a new dimension of customization controlled by a magnetic field. Because these materials may be applied to protective gear like helmets, having the ability to change according to environmental stimuli is critical.

This new class of metamaterials opens the door to dynamic components in a variety of areas. In addition to adaptive helmets, smart wearables that reduce vibrations, perhaps armor, could be on the way. Any application with movement control could benefit, such as car seats stiffening during a crash. Shoe soles have already incorporated mechanical metamaterials to improve impact absorption, and similar ideas can be applied to make buildings more earthquake-resistant or jet engines more thermally stable. With more testing, materials that stiffen up when needed most may soon be solidified.

SUPERCONDUCTING CIRCUITS AS ARTIFICIAL ATOMS

BY JAMESON O'REILLY, PHYSICS & MATHEMATICS, 2019
DESIGN BY LILLIE HOFFART, ENVIRONMENTAL SCIENCE, 2022

For the last several years, hundreds of scientists have been toiling away across the globe to develop quantum computers. Rather than using binary logic for computation, these machines utilize the rules that govern the behavior of the smallest and coldest constituents of our universe. If all goes according to plan, someday quantum computers will tackle certain problems that would take a normal supercomputer longer than the projected lifetime of the universe to solve. One way to build a quantum computer is by using these smallest, coldest things, such as atoms or molecules, directly, but existing computing companies do not have prior experience with these techniques.

Another method, the one pursued by Google, Microsoft, Intel, and IBM, is to use superconducting electrical circuits instead. While pursuing this avenue does require the development of new technology, the tech giants can lean on their expertise in fabricating more traditional circuits on a large scale. They can extend their current technology rather than building expertise in a new field from scratch.

At first glance, it is not obvious how to encode and manipulate quantum information using an electrical circuit. Quantum mechanics typically describes single particles with discrete properties, but circuits typically contain many particles and have continuous properties like voltage and current. The key is to build the circuit out of special materials and cool them, typically below 1 Kelvin, until they begin to superconduct.

When electrons move through normal materials, they bump into things and experience resistance that stops them from flowing freely. In a superconductor, all of the electrons form Cooper pairs, which altogether act as one quantum entity that can flow through the superconductor without any resistance. In some sense, they form one pure quantum system with its own set of discrete states, much like an atom or molecule.

> "The key is to build the circuit out of special materials and cool them, typically below 1 Kelvin, until they begin to superconduct."

The superconducting circuit approach has led to slow but steady progress, and the companies involved have generated a massive amount of press, with the most recent headlines being dedicated to IBM's unveiling of the Q System One. It is marketed as the "first integrated universal" quantum computer and should be available for use by select companies and research institutes over the cloud in the second half of 2019. With only 20 qubits, the quantum analogue of classical computer bits, this system will not outperform many laptops, let alone supercomputers, on any tasks. Its main utility for IBM is to signal that they are moving in the right direction and that larger systems, which will be more directly useful, are on the horizon. Meanwhile, their clients can use the Q System One to assess how the future generations of quantum computers will best be put to use.

Most of the press about quantum computers has focused on superconducting systems because of who works on them, but there are also scientists working on building quantum computers based on atomic systems. Atoms cooled to much less than 1 Kelvin with laser light are a pristine quantum system. Quantum information can be encoded in energy levels of their valence electrons and manipulated by shining microwaves or optical lasers on the atom and driving the relevant electron into another level.

In many ways, superconducting quantum computers are just mimicking these cleaner atomic systems. On the other hand, they can be built, albeit imperfectly, within the production framework that computer companies developed for microprocessors. This has given tech companies a huge advantage over the people working to build large, useful quantum computers based on atomic systems, but only time will tell whether or not a synthetic atom can compete with the real thing.

PHOTO BY PIXABAY

Bioplastics: A boon or a blunder?

Should we reconsider our use of bioplastics?

BY OLIVIA CLAUSEN, ECONOMICS & ENVIRONMENTAL STUDIES, 2021

It is estimated that by 2050 there will be 12 billion metric tons of plastic waste in oceans and landfills, according to researchers at the University of California, Santa Barbara. There is already more than 8.3 billion tons of plastic waste in landfills and oceans to date. If that is hard to visualize, imagine the island of Manhattan filled 250 feet high with plastic litter.

Despite improved recycling efforts in the past 30 years, 79 percent of plastic still ends up in landfills and in the environment. This has led to a search for promising plastic alternatives—one being bioplastic.

According to the Society of the Plastics Industry, bioplastics are either biodegradable, have bio-based content, or both. Instead of non-biodegradable chemical compounds such as polyethylene, bioplastics may be made from renewable resources such as corn, rice, or vegetable oil.

While plastics made from fossil fuels biodegrade less than 10 percent, bioplastics have been measured to be more than 90 percent biodegradable. Testing biodegradability is a straightforward process: a plastic sample is exposed to an aerobic environment such as soil, and a measurement is taken of the carbon dioxide evolved as microbes consume the material. This provides an exact measurement of the plastic's carbon being used. These tests have determined that bioplastics are much better at being broken down by the natural environment and are therefore much less likely to end up in landfills or polluting oceans.

Although bioplastics may be proven to be more biodegradable than conventional fossil fuel-made plastics, they come at an ethical cost. Many bioplastics are made from food sources: corn, sugar, potatoes, and other agricultural resources that need fertilizers to grow, and could be feeding people instead of being used for plastics. The intensive land use required to grow these resources takes a toll on the environment as well, causing researchers to debate whether bioplastics have a cumulative positive effect.

Over the next five years, the global market for bioplastics is expected to grow by 20 percent. Right now, it is difficult to conclude whether bioplastics are an efficient way to combat environmental issues. Until that is discovered, the best thing people can do is minimize their personal consumption to avoid the looming vision of Manhattan filled to the brim with plastic waste.

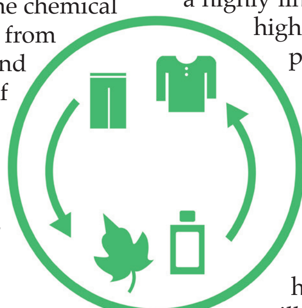
Soil Degradable Bioplastics for a Sustainable Modern Agriculture (2017). DOI: 10.1007/978-3-662-54130-2_2
Science Advances (2017). DOI: 10.1126/sciadv.1700782

PHOTO BY WIKIPEDIA

Coal to castor oil: A more sustainable polyester material

BY MAYA KRAUSE, ENVIRONMENTAL SCIENCE, 2022

Fossil fuels are ingrained in nearly every aspect of 21st century life, from transportation to cooking to clothes. Worldwide, about 60 percent of all clothes produced are made from synthetic fibers, according to the International Cotton Advisory Committee. One of the more common synthetic fibers is polyethylene terephthalate (PET), also known as polyester material. Polyester material is comprised of a specific kind of polymer chain, known in the chemical community as polyester, which is derived from fossil fuels such as coal and petroleum. And as the destructive environmental impacts of sourcing fossil fuels and disposing of synthetic fibers become increasingly apparent, chemists have been searching for a more sustainable alternative to polyester material. Dr. Ye Liu and Prof. Dr. Stefan Mecking from the University of Konstanz claim to have found just that.



Liu and Mecking were able to derive a synthetic polyester equivalent in function to the polymer chain found in PET from a polymer found in castor oil. Castor oil is produced from the seed of the castor bean, Ricinus communis, which commonly grows in tropical and Mediterranean climates. Castor oil contains the polymer undecenol ($C_{11}H_{22}O$), and through a single-step chemical process, the researchers converted undecenol into a synthetic polyester that serves the same purposes as commercial polyester material.

Liu and Mecking describe the specifics of this process in their article "Synthetic Polyester from Plant Oil Feedstock by Functionalizing Polymerization," published in the German Chemical Society journal Angewandte Chemie. They used a single catalyst to speed up the addition of carbon monoxide to the undecenol polymer. The catalyst was able to produce a highly linear polyester with a large molecular weight and high boiling point under moderate temperatures and pressures. This substance and its production are similar to those of current polyesters derived from fossil fuels, which means transitioning to using the undecenol polyester would not be challenging.

Liu and Mecking's research could mean a new future of synthetic clothing is on the horizon. Many industries reliant on fossil fuels will find ways of replacing this resource as sources are depleted. The ease and functionality of the conversion of undecenol to polyester could be revolutionary as the textile industry searches for a new, non-fossil fuel polyester material. This research also shows other industries in need of replacement resources that the solution may lie not in fossil fuels, but in more sustainable sources.

Angewandte Chemie (2018): DOI: 10.1002/anie.201810914

DESIGN BY KAI GRAVEL - PUCILLO, ENVIRONMENTAL SCIENCE, 2021

ARTIFICIAL BY DESIGN

BY SYEDA HASAN, BEHAVIORAL NEUROSCIENCE & GLOBAL HEALTH, 2020
BY COLIN THOMPSON, ENVIRONMENTAL SCIENCE, 2019
DESIGN BY LILLIE HOFFART, ENVIRONMENTAL SCIENCE, 2022
PHOTOS BY GUS MUELLER

This article was written in collaboration between NU Sci and The Avenue, Northeastern's fashion and culture publication. Look for The Avenue's "Devotion" edition, coming March 27th for more looks from this photoshoot!

If you're remotely fashion-inclined, you may have noticed that many designers are co-opting more renewably sourced fibers. In fact, this idea of "greenwashing"—the phenomenon describing companies disingenuously advertising green production, practices, and policies—has plagued not only the fashion industry, but also has made its way into corporations such as PepsiCo. Organic cotton is in; it may just be our way out of a toxic textile industry. More and more brands like Everlane and Able are discovering the magic of livable wages and safe working conditions. But what exactly are renewably sourced fibers? What makes them any different than the man-made, highly commercialized polyester or nylon? Does sustainable material always entail ethical production?

"Eco-friendly" materials include naturally sourced fibers, like bamboo and hemp. Alternative fibers, like Ingeo fiber, are also eco-friendly synthetics but do not rely as heavily on finite oil resources as polyester and nylon do. These options are undeniably more sustainable than utilizing fossil fuels to manufacture polyester and other unsustainable materials, but what are the long-term environmental implications of these products going to be? In 2008, NatureWorks began manufacturing textiles like Ingeo fiber—derived from plant material in an effort to curb the constant use of petroleum in synthetic textiles. This process used 62-68 percent less fossil fuels than traditional methods. Not only could these materials also be composted, but they reduced greenhouse gas emissions by 80-90 percent. Imagine what a world with these sustainable practices could look like!

As it stands, current practices around the manufacturing of synthetic textiles raise concerns over microfiber shedding, which leads to to microplastic pollution. That's not to say that natural fibers like cotton and wool are perfect, either. In fact, natural fibers also require significant amounts of water. However, the impact of microplastic solution is a heavy one. Synthetic textiles account for 35 percent of microplastics entering oceans. In a 2016 study looking at microfiber waste collected from conventional washing machines, it was estimated that a population of 100,000 people can produce almost 1.02 kilograms of microfibers every day and 793 pounds every year. These microplastics inevitably reach the ocean, where they can enter the diets of marine life. About 73 percent of fish caught at mid-ocean depths were shown to have microplastics in their stomachs. As for the waste that isn't eaten by marine life, a lot of it ends up on the ocean floor or other inaccessible parts of the ocean, making it hard for researchers to fully understand the environmental impacts they impose.

While novel ideas such as these are now hitting the mainstream, there are a couple of brands that are taking sustainable textiles and building entire brands around them. Stella McCartney, a brand using vegetarian leather and polyester based fur, has advocated for the use of sustainable synthetics. In 2017, the brand began working with Bolt Threads, a startup that specializes in the synthesis of artificial spider silk. The yeast-based protein threads are able to hold dye easier, requiring less water and dyes during the dyeing process. While this news is very exciting, it's pretty common for these experimentations to be squirreled away to the high fashion industry. It can be said that the use of such textiles is more of a public relations stunt than a product that can be purchased by the general public. This definitely was the case with Stella McCartney, as these products have yet to hit online retailers.

"SYNTHETIC TEXTILES ACCOUNT FOR 35 PERCENT OF MICROPLASTICS ENTERING OCEANS."

Nike, with its global brand recognition, has also moved towards sustainable production methods. While traditional leather manufacturing involves the disposal of portions of cow hides, Nike instead uses discarded leather and turns them into fibers. From there, they are combined with synthetic fibers and fused into one material. While Nike is still operating in the space of traditional leather making, these efforts to integrate the use of synthetic fibers in products help to alleviate environmental impacts caused by industry.

Ingeo fibers, manufactured by NatureWorks, use plants like corn, sugar cane, cassava, and beet to seize carbon dioxide and transform it into long chains of sugar molecules, known as polymers. Glucose is then extracted from the plants and turned to dextrose. Dextrose is the naturally occurring form of glucose that is derived via the use of small catalytic molecules, known as enzymes, and a chemical reaction with water, known as hydrolysis. Dextrose is fermented using microorganisms, and produces lactic acid. Rings of lactide, essential to the synthesis of Ingeo fiber, are derived from the lactic acid and polymerized. Finally, long chains of polylactide (PLA) polymer, known as Ingeo fiber, are created from this process.

If the long-drawn and meticulous manufacturing process of Ingeo fiber tells you anything, it is that a large investment of time and coinage need to be made for its production to be possible. Despite these textiles reducing greenhouse gas emissions and revolutionizing the face of sustainable fashion, Ingeo fiber has its drawbacks. According to Maria Burke of Chemistry World and Josef Spikyers of CIRFS, the European man-made fibers industry association, "[…] they are so far only used in niche markets because they cost several times more than regular polyester and their performance properties are not so good."

Ingeo fiber is not alone in its struggle to entice the excitement, and quite frankly, the pockets of consumers. The company of Lenzing, based in Austria, uses wood pulp in the making of Tencel. Tencel is 50 percent more absorbent than cotton, but costs a third more than viscose, which is used to manufacture rayon. Now, the only question that remains is whether consumers are as devoted to their environment as they are their wallets.

With all of these barriers to becoming an ethical consumer, it can be easy to think of the effort as obsolete. The greenwashing of labor practices can essentially render any allegedly sustainable production as paradoxical. Specifically looking at the whopping 80 percent of factory workers who are women, the negative health outcomes of an unsafe working environment are incredibly disproportionate. Additionally, while many companies implement minimum wages as per their countries, they do not implement livable wages that consider garment workers' abilities to afford food, rent, healthcare, transportation, and education. Brands that emphasize paying their workers minimum wage are only doing what is legal, the bare minimum, and not necessarily what is ethical.

As a consumer devoted to holistically sustainable fashion, it can be hard to come across brands that check all the boxes. Brands that ensure living wages for their workers are not always devoted to producing sustainable materials. Alternatively, there are existing brands that boast sustainable products but are only accessible to niche, more elite communities. At what point do we delineate corporate responsibility and personal responsibility? Brands like Stella McCartney that aspire to revolutionize sustainable fashion only seem to be doing so for those who can afford it. Nike, despite all its efforts, still perpetuates only partially sustainable models and owes more transparency to its consumers concerning factory working conditions.

While it seems like we might be moving towards policies and practices to protect us from falling victim to greenwashing brands, there are still a number of things that we can do to ensure our fashion is fair. Washing our synthetics less can cause less detriment to oceans. We can try to shop less and, when we do, shop local or second-hand. And lest we forget, being an ethical consumer means doing your research. The more you know about the ethics of your clothing, you'll undeniably be happier wearing them.

MODELED (L TO R) BY SYEDA HASAN, MILLIE LANG, AND SYDNEY LERNER

International Union for Conservation of Nature (2017). DOI: dx.doi.org/10.2305/IUCN.CH.2017.01.en.
Environmental Science & Technology (2016). DOI: 10.1021/acs.est.6b03045.
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Lab-grown meat: What's the beef?

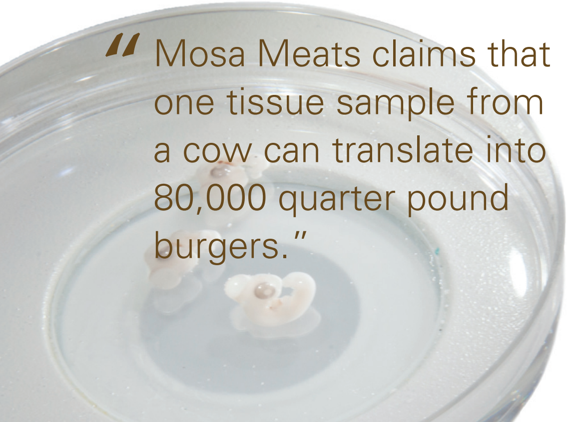
BY YAEL LISSACK, BIOENGINEERING, 2021

DESIGN BY IAN PROULX, BIOENGINEERING, 2022

What do coal tar, asbestos, mustard gas, and beef jerky have in common? They're all identified as Group 1 carcinogens by the International Agency for Research on Cancer (IARC). Following suit in 2015, the World Health Organization declared red meat as a Group 2A probable carcinogen and has specifically placed processed meat into the known carcinogen Group 1 category. In an epidemiological study by the World Cancer Research Fund and IARC, it was found that eating 50 grams of processed meat a day—equivalent to about just four slices of bacon or one hot dog—increased the risk of colorectal cancer by 16 percent. This information quickly made headlines, and there has been a tremendously powerful response to this announcement.

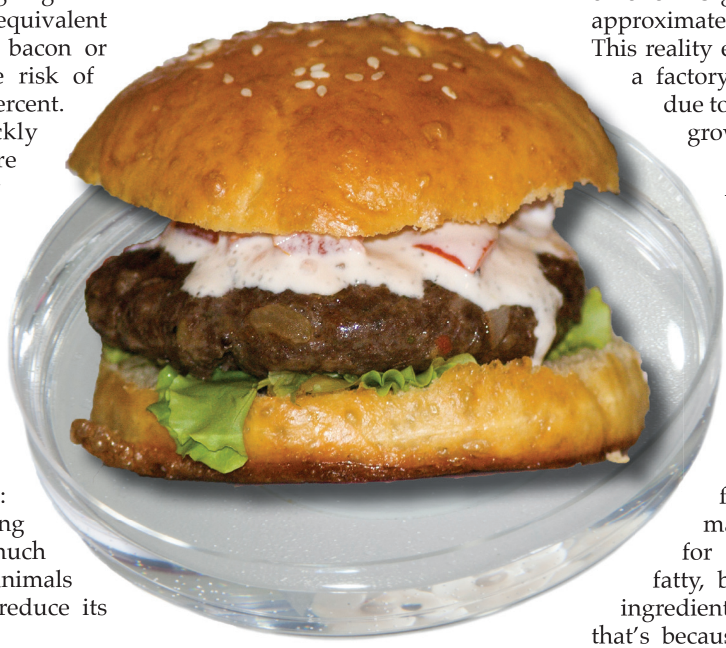
Due to the health risks associated with meat as well as its huge environmental impact, companies are shifting away from traditional factory-farm raised beef and towards a new alternative: lab-grown meat. This emerging industry strives to alleviate much of the cruel treatment of animals raised for food as well as reduce its environmental footprint.

Also called "clean meat," lab-grown meat begins with a live animal's stem cells. These cells are placed into a rich nutrient-dense medium, incubated, and expanded. They are then differentiated into muscle fiber cells and allowed to proliferate for approximately six weeks. Once about 20,000 muscle fiber cells have matured, they are then harvested, minced, colored, and mixed with fats and spices. With this procedure, the company Mosa Meat claims that one tissue sample from a cow can translate into 80,000 quarter pound burgers.



> "Mosa Meats claims that one tissue sample from a cow can translate into 80,000 quarter pound burgers."

This same process can be applied to any type of live animal tissue. The Tel-Aviv based company SuperMeat is focusing its efforts on poultry. Another company called Finless Foods even claims to have lab-grown bluefin tuna arriving on the menu in 2019. With a long lifespan



of 15-30 years, bluefin tuna is especially vulnerable to predatory fishing practices like overfishing. Ultimately, their efforts promise fish free of arsenic, mercury, plastic, and other environmental detriments.

With outstanding returns like these, lab-grown meat has captivated investors and consumers alike. The company Memphis Meats is one of the giants in the industry, having received over 17 million dollars from various investors such as Bill Gates in 2017 alone.

Though lab-grown meat is a growing industry, it is still very much an industry of the future. In 2013, Mosa Meat revealed a lab-grown beef patty which cost a striking 300,000 dollars to produce. For lab-grown chicken, Memphis Meats' production costs 6,000 dollars per pound. With the introduction of new companies in the race for the highest quality and most affordable lab-grown meat, many still have a ways to go before reaching the average consumer.

According to the Food and Agriculture Organization of the United Nations, the livestock industry accounts for a staggering 14.5 percent of all greenhouse gas emissions—with the production of one 113-gram patty of beef using approximately 1799 gallons of water. This reality emphasizes the urgency of a factory farming alternative. But due to its staggering price, is lab-grown meat the only option?

A company called Impossible Foods is pioneering a wildly successful plant-based meat. Their Impossible "Meat" is made from wheat and potato proteins for texture, vitamins, amino acids, and heme, all blended to represent the juicy, flavorful burger enjoyed by many. The patty is acclaimed for its meat-like texture and fatty, blood-like juiciness. If the ingredient heme sounds familiar, that's because it's the same molecule that carries oxygen in blood and gives it that deep red color. What's not as familiar is that this molecule is found in every living organism, and the heme used in the Impossible patty comes not from animals, but from the root of the soy plant. Importantly, this burger only costs $11 in restaurants across America.

With many options out there for those interested in sustainable meat, it all comes down to the basics: quality, affordability, and taste. Whether you're a meat lover looking for a tasty yet ethical dinner or a vegan seeking a childhood favorite, this next generation of meat seems to be the solution towards a more sustainable future.

Lancet Oncology (2015). DOI: 10.1016/S1470-2045(15)00444-1

PHOTOS BY FLICKR

WHERE'S THE BEEF?

Examining the advertising promise of "100%"

BY RAFI RAZZAQUE, ENVIRONMENTAL SCIENCE, 2019

DESIGN BY KYLA VIGDOR, DESIGN, 2021

Every so often, another fast food franchise promotes their newest creation with a '100 percent' tag, as if to assure their consumers of the content and freshness of their new products. For food, be it beef, juice, or syrups, there are tough regulations surrounding advertising terms; and in other cases, shrewd but potentially misleading advertising lingo has circumvented these regulations. What's the deal behind these promises?

Within the US, federal food agencies such as the United States Department of Agriculture (USDA) and Food and Drug Administration (FDA) dictate some of the language food corporations can use in product branding. Notably, the USDA oversees the inspecting and grading of meat and poultry. By USDA standards, food labeled "ground beef" must be composed entirely of ground beef, permitting a 30 percent fat content; therefore, the '100 percent ground beef' tags seen do not necessarily mean the meat is lean, fat-free, or fresh. Rather, the '100 percent' designation means no further ingredients are added to the meat; this also applies to cheese products, where the '100 percent' designation cannot be used on cheese that contains imitation or food product cheese. The USDA also has quality assurance certifications for certain production processes: hickory-smoked products can only be labeled as such when an inspector certifies that the wood used in the smoking process is 100 percent hickory.

> "The '100 percent ground beef' tags seen do not necessarily mean the meat is lean, fat-free, or fresh."

According to the FDA, juices must mention the percentage of juice if the beverage purports to mention or represent juice. The amount of juice in the beverage must be mentioned in a percentage above the nutrition label; however, a beverage that says it contains '100 percent juice' is not necessarily entirely that juice. Rather, the '100 percent' label solely comments on the juice makeup, excluding added ingredients such as sugar or preservatives (i.e. where the nutrition label would suggest '100 percent juice with added sweetener').

However, areas where the FDA and USDA do not heavily regulate the use of '100 percent' come into shadier, potentially misleading use. For example, the FDA does not well define the term 'natural', noting in its website that "it is difficult to define a food product that is 'natural.'" As such, individual companies are free to define '100 percent natural' as they wish, with results that may confuse consumers. General Mills dropped the use of '100 percent natural' in its Nature Valley granola bars following a lawsuit alleging the use of glyphosate, a weed-killing carcinogen, in bars. Recently, products such as Juicy Juice and Tyson Chicken have utilized the term "all natural" to imply a degree of quality and nutrition, circumventing government regulations on using '100 percent natural'.

Conversely, the term 'organic' is better protected by federal agencies. The USDA insists that '100 percent organic' products must contain entirely USDA-certified organic ingredients, with no tolerance for non-organic ingredients, including processing aids. Comparatively, a product wearing an organic label can be up to 95 percent organic ingredients.

Lastly, it is worth noting when the '100 percent' labels are not used. With the '100 percent' tag heavily defined by the USDA, its omission in certain scenarios potentially raises red flags. A 2017 test by a Canadian Broadcasting Corporation show investigated chicken products from several fast food joints, sending samples for DNA testing. Within their tested group, the samples were never higher than 90 percent chicken DNA; some of the samples registered less than 50 percent. Largely, they found the remaining DNA in these meals to be soy, despite rebuttals from the respective companies that claimed they could not release ingredient percentage breakdowns for 'competitive reasons.' By and large, with the USDA relatively tight on the use of '100 percent' labels, it is worth questioning the products that do not meet the qualities to use that certification; and if so, why not.

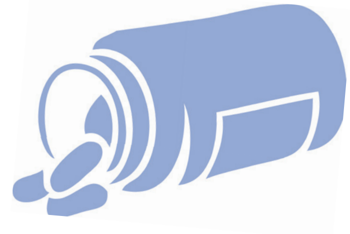
Use of the '100 percent' figure in the food industry is regulated by a series of stipulations on the content and production of the product; however, it does not necessarily promise health or freshness but merely the composition of its ingredients. Given the rise of people who seek healthy foods—a 2015 Forbes article found 88 percent of people are willing to pay more for healthy foods—it is important that people seeking healthy options can do so without being misled. The regulations on the 100 percent moniker in the US mean that consumers can mostly trust products that feature it, so long as they are vigilant about what 100 percent means for the nutritional, qualitative, and dietary makeup of their next meal.

American Journal of Law and Medicine (2015). DOI: 10.1177/0098858815591522

PHOTO BY FLICKR

Synthetic estrogen:

From pill to pond



BY HUGH SHIRLEY, BIOCHEMISTRY, 2019

DESIGN BY KAI GRAVEL–PUCILLO, ENVIRONMENTAL SCIENCE, 2021

In its natural state, estrogen is a steroid hormone produced primarily by the ovaries. Its effects on the human body are numerous and impactful, as in the development of female sex characteristics or as a regulatory molecule in the menstrual cycle. When we think of estrogen, we are generalizing a group of similar compounds that exhibit estrogenic activity. The human body isn't the only body that estrogen can act upon. All vertebrates produce estrogen in one or more of its major forms, using it for female characteristic development. The dramatic impacts that estrogen can have on the animals in and around human habitats are important for their own development, but when we interfere, things can get messy.

The major forms of estrogen are each characterized by their relative estrogenic potency. They can cause a greater reaction at a lower concentration in the body. Women, and men to a lesser degree, naturally produce estrone, E1, estradiol, E2, and estriol, E3. Each serves a purpose and is synthesized at higher rates during different points of the human life cycle. Estradiol, the primary estrogen during reproductive years, is 10 times more potent than estrone, the primary form during menopause, and 100 times more potent than estriol, the prevalent form during pregnancy.

Estrogenic compounds are important for health and development for multiple reasons. Estrogen receptors are located on cells throughout the body, coordinating many of the physiological differences between men and women. From the brain to the bones, estrogen has a dramatic impact on many organ systems. However, most people probably associate estrogen with the menstrual cycle. Normally, estrogen levels spike right before ovulation, but contraceptive pills contain synthetic estrogen, called 17α-ethinylestradiol, or EE2, that keeps estrogen levels high all cycle long, tricking the body into thinking it's already pregnant; this synthetic estrogen is proving the most problematic.

EE2 is a manmade estrogen more potent than any naturally-occurring form of estrogen. Not only is it used for contraceptive pills, but the powerful hormone is used for livestock and aquaculture, too. Regardless of where we use it, some EE2 inevitably ends up in the environment around where it's used partially due to EE2's longer half-life than endogenously-produced estradiol. The 17α-ethinyl group on synthetic estrogen prevents natural degradation that would normally mitigate the release of estrogens into the environment. For livestock, that environment means downstream of the farm, and for humans, that means in the sewers, to the waste treatment plants, and then out to the rivers that take our waste away. The hormone has been found in biologically-significant concentrations all over the world. The question isn't if this is happening, it's what happens next.

To answer that, studies have examined the effects of EE2 on different organisms at different concentrations. Both controlled settings and direct observation of an EE2-contaminated environment have shown how the chemical has a profound impact on the ecosystem. Over the long term, EE2 exposure leads to decreased reproductive ability and even species feminization, the conversion of male to female characteristics. EE2 in the water supply has been linked to increased rates of breast cancer. While these relationships have not been fully explored and studied, it's clearly traveling from human sources into the environment and having unintended consequences, both in the ecosystem around us and our own bodies.

A solution to the EE2 problem is not fast coming. The widespread use of synthetic hormones in multiple industries isn't slowing down, which makes finding a solution to estrogen contamination an important field of study. Understanding the technology that we already have can prove beneficial. The current work revolves around a downstream mitigation strategy, like using enzymes that break down estrogens. While trying to break down EE2 after it has entered the environment has the potential to reduce ecological harm, this strategy is a band-aid at best. The cause of the issue is the use of synthetic hormones and the inability of our waste systems to deal with removing contaminants down to concentrations where EE2 wouldn't be able to impact ecosystem health.

The issue of hormone, and specifically estrogen, contamination does not have widespread societal visibility. Despite the power of hormones, with their functions dominating many physiological pathways and working to maintain homeostasis in virtually all multicellular organisms, we have yet to realize their potential for ecological harm. Synthetic versions of hormones, useful because of how important and powerful hormones are, carry the additional burden of disastrous consequences or their potency and resilience.

Toxicology and Applied Pharmacology (2000). DOI:10.1006/taap.2000.8912

Toxicology Letters (2012). DOI: 10.1016/j.toxlet.2012.03.020

GRAPHICS BY PIXABAY AND AMERICAN CDC

EXPLOSIVE-SMELLING ROBOT LOBSTERS:

A four-decade project

BY BINH DANG, ENVIRONMENTAL SCIENCE, 2022

DESIGN BY KYLA VIGDOR, DESIGN, 2021

As I trekked up the spiral staircase to the fifth floor of Northeastern's Interdisciplinary Science and Engineering Center, I was greeted, first, by a dormant automaton, and second, by its creator. He asked me what I wanted to know. I replied, "Just start from the beginning."

Like any great story, he began with, "In the seventies…"

Professor Joseph Ayers, a neurophysiologist at Northeastern University, has dedicated decades studying neuronal pathways, innate movement, and neuromodulation—the changes in nerve activity that mediate adaptation—through robotics.

"When I say innate behavior, I mean the stuff you're born with. We can learn how to speak a foreign language or play a musical instrument, but we all walk in human," he explained.

Ayers was one of the first neurophysiologists to embrace a paradigm of both identifying individual neurons in crustaceans and recording the connections of neurons to identify larger, behavior-controlling networks. He focused on studying lobsters and lamprey specifically because individual command neurons—which instigate an action—orchestrate their behaviors.

Ayers was supported by Defense Advanced Research Projects Agency to develop controllers for biomimetic robots based on computational models of lobster and lamprey nervous systems. In other words, he effectually created a mathematical model of a lobster's nervous system.

However, like any robot, it had limitations: it could only do what it was programmed to do. If the robot became stuck under a rock, it had no way to become unstuck unless it was programmed to escape every possible situation.

To solve this dilemma, Ayers realized that he needed to control the robots with actual neuronal networks. He started collaborating with physicists who had begun studying the degrees of freedom of neurons—how many states in which they can exist—to assess their dynamical organization.

"There's probably a hundred degrees of molecular freedom in a neuron. So, my colleagues at the Institute of Nonlinear Science at University of California San Diego did nonlinear dynamical analyses and determined that a neuron only has four degrees of dynamical freedom, and they came up with four equations to represent them," he said. "If you built an analog computer that solves these equations in real time, it's pretty much indistinguishable from a living neuron." This model had something that algorithmic programming didn't: variable chaos.

"That's the difference between an animal and a robot. When an animal gets stuck, it can wiggle and squirm. We're convinced that when animals are doing that, what they're doing is increasing the level of chaos in the networks that would otherwise generate locomotory patterns, and these variations in the walking pattern underlie the wiggling and squirming" he said. "So all of our robots now have electronic neurons that have variable chaos."

Until this point, Ayers' research focused on studying the movements of animals and the adaptability of variable chaos through robotics. In 2009, the Engineering and Physical Sciences Research Council of Great Britain and the National Science Foundation put out a request for proposals in synthetic biology. Naturally, Ayers took up this offer, assuming his biomimetic research was applicable. He was quite surprised to discover, however, that synthetic biology was actually the new name for genetic engineering and molecular biology—not robotics.

Ayers now works with Northeastern Assistant Professor of Civil and Environmental Engineering Dr. Amy Mueller and graduate student Jason Derks to give these robots a sense of smell. This is made possible by using yeast as a platform—an organism that is genetically modified to receive traits not found in nature—to insert a gene for an olfactory receptor. This receptor (olfactory receptor 226) allows dogs to smell explosives. When the odorant binds to the olfactory receptor, it activates an internal signaling pathway to activate a calcium channel.

After that, the calcium pathway, coupled with a cofactor, or supplemental molecule necessary for enzyme activation, activates nitric oxide synthase. When expressed in the yeast, this produces nitric oxide— a substance that normally activates budding of the organism. The yeast then forms a biofilm on a nitric oxide electrode on the robot lobster, which allows the robot to essentially smell explosives.

This project also compounds on Ayers' past research. The robot combines the programmed behaviors of the lobster with sensing explosives, so it's very clear when they're identified.

"When you think about the set of behaviors that a lobster does, when it's sniffing out a lobster trap to get food, we know what those [behaviors] are…So this is going to be the most advanced mine hunting robot there is."

Your torn trousers can turn over a new weave!

Scientists have invented self-repairing textiles using proteins obtained from squids

BY SHARVARI AJIT DEEPTI NARENDRA, BIOINFORMATICS, 2020

DESIGN BY KRISTI BUI, COMPUTER SCIENCE, 2021

Researchers at Pennsylvania State University have developed a 'tailor-made' fix for frayed fabrics—self-repairing textiles. Using proteins acquired from squid teeth as a coating, a material can heal itself upon application of warm water. Metal, plastic, and ceramic industries had already been introduced to self-repairing products, which are now being used by the textile industry. These materials show promise, increasing the shelf life of the respective product while helping consumers heal their ripped wallets. Melik Demirel, a materials scientist and professor at Penn State, along with a team of scientists from the U.S. Naval Research Laboratory, worked on self-repairing textiles with broader applications in mind; self-healing fabrics to protect farmers from being exposed to harmful pesticides, soldiers on the battlefield from chemical and biological attacks, and industrial workers from exposure to toxic chemicals.

To create a fabric that had a self-healing coating, the researchers took inspiration from the biological healing properties of the squid. The suction cups of the squid, which are used for hunting, are lined with teeth. These teeth possess a particular protein that contains two types of segments: hard segments, and amorphous, or soft, segments. The hard segments physically cross-link with each other, while the soft segments are bound together by hydrogen bonds when in contact with water. These soft segments aid in fusing severed proteins together in the presence of water, while the hard segments build the structure of the proteins back to its original form. This formula was applied by the scientists at Penn State for repairing torn textiles. For smaller tears, layers of polymers that are oppositely charged can be used to form a film. When the film is scratched and exposed to water, the oppositely charged polymers undergo an ion exchange process that begins inside the film and moves to the surface, thus healing the crack. Polymers like polyethylenimine and polyacrylic acid are used to form such films; however, since they only repair tears that are thin in width, the squid proteins were used for larger tears instead. The squid proteins that are positively charged were combined with polystyrene sulfonate, a negatively charged polymer, ultimately creating a one micrometer thick coating by dipping the fabric into these two solutions. Depending on what kind of toxin is needed to be broken down and whom the fabric is intended for, a layer of the respective enzyme is added. The Penn State researchers added urease, an enzyme that breaks urea down into ammonium carbonate, while formulating their self-repairing textile. However, according to Professor Demirel, enzymes such as organophosphorus hydrolase, involved in the break down of organophosphate pesticides, can also be used. A final protein layer was added, and the coating was ready to be tested with a scratch - and, voila! Not only were the textiles repaired, but they attained the same quality as they originally possessed before they were cut.

"Not only were the textiles repaired, they attained the same quality as they originally possessed, before they were cut."

The Penn State team is now aiming to create the self-healing proteins without using the squid, and they would like to test the fabric in real life situations, such as in a washing machine. Mankind has certainly come a long way from using plants as a part of their clothing to creating self-repairing textiles to heal tears created by those very plants. The medical field, in particular, is enthused about the future prospects of these fabrics, as coatings on medical meshes could help patients recover faster from wounds by reducing infections. Self-repairing textiles have already been debuted in the fashion and technology industry, when Imperial Motion, a lifestyle brand from Tacoma, used 'Nano Cure Tech' to launch two self-repairing jackets in 2017, wherein a hole could be healed by rubbing two fingers across it for merely 10 seconds. The future of self-repairing textiles surely seems bright. But will a stitch in time save nine? Only research will tell.

PHOTO BY PIXABAY

BECOMING ROBOT

Cell-sized robots could be a new addition to the human body

BY NOLAN PICCOLA, JOURNALISM, 2022

PHOTO BY FELICE FRANKEL

The human body is composed of trillions of cells, each with the purpose of carrying out a specific function. From skeletal cells to nerve cells, the body relies on these basic building blocks to survive. While these building blocks will never change, a new age of cells is on the horizon.

Researchers at MIT have recently developed microparticles known as “syncells”, short for synthetic cells, which are comprised of two-dimensional materials with unique electrical, mechanical, and chemical properties. Syncells are roughly the size of a red blood cell, measuring about 10 micrometers wide. In addition to their similar size to a biological cell, synthetic cells also hold a comparable appearance to these small units of life.

In their interior, syncells contain electric circuits and other materials that have the ability to store and collect information in the environment they are placed in. Because the size of these particles is one thousand times smaller than any previous study, they have the unique ability to enter previously inaccessible environments. These cell-sized robots hold a wide array of functions.

Specifically, syncells could aid the human body in identifying diseases such as cancers in different areas of the body. Industries could also benefit from these cells in monitoring oil pipelines by storing information on whether the pipeline is functioning in a safe manner.

During the experiment, researchers used a unique technique in creating the colloidal particles (solid microparticles suspended in a fluid) known as auto-perforation. This method, as stated in the paper published in Nature Materials in 2018, “provides a means of spontaneous assembly for surfaces composed of two-dimensional molecular scaffolds.” In addition to a simple assembly, the particles also generate a significant amount of conductivity on their surface, providing the scientists with a method of tracking the particles through a plane.

While mass-development of these robots is likely years away, the possibility of synthetic cells making up the human body is no longer just an idea. Soon, our skeletal and muscle cells could co-exist with micro-robots.

Autoperforation of 2D materials for generating two-terminal memristive Janus particles (2018). DOI: 10.1038/s41563-018-0197-z

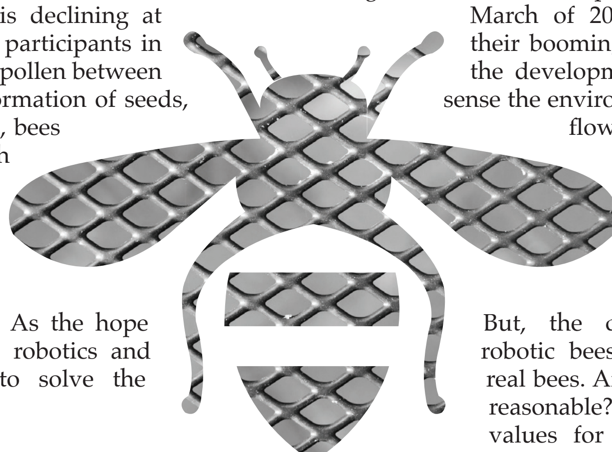
Are robotic bees the solution for the lack of buzz?

Can autonomous drones fix the pollination problem?

BY CAILEY DENONCOURT, BIOENGINEERING, 2022

On a future, bright summer day, the classic buzzing sound may no longer stem from the rapid beating of a bee’s wings, but rather the rapid whirl of the blades of a drone.

Despite all the continuing efforts to save the bees, the bee population in North America is declining at a rapid rate. Bees are the main participants in cross-pollination, the transfer of pollen between flowers, which allows for the formation of seeds, nuts, and fruits. In the US alone, bees contribute to $19 billion worth of crops, which is about one-third of all the food eaten. Thus, their impending demise greatly impacts our agriculture, directly affecting the food on our dinner plates. As the hope of saving the bees diminishes, robotics and biomimicry are stepping in to solve the pollinator problem.



About a decade ago, at Japan’s National Institute of Advanced Industrial Science and Technology, Eijiro Miyako accidentally developed an ionic liquid with very low reactivity. In 2017, he realized its potential. Miyako developed an idea to use this gel-like substance as a way to artificially pollinate plants by mimicking the sticky hairs on a bee. These hairs completely covering a bee’s body have the ability to pick up and retain pollen particles that then transfer to all the subsequent flowers the bee visits. By attaching this gel to a small drone, Miyako was able to remotely transfer pollen between flowers, just as a bee does.

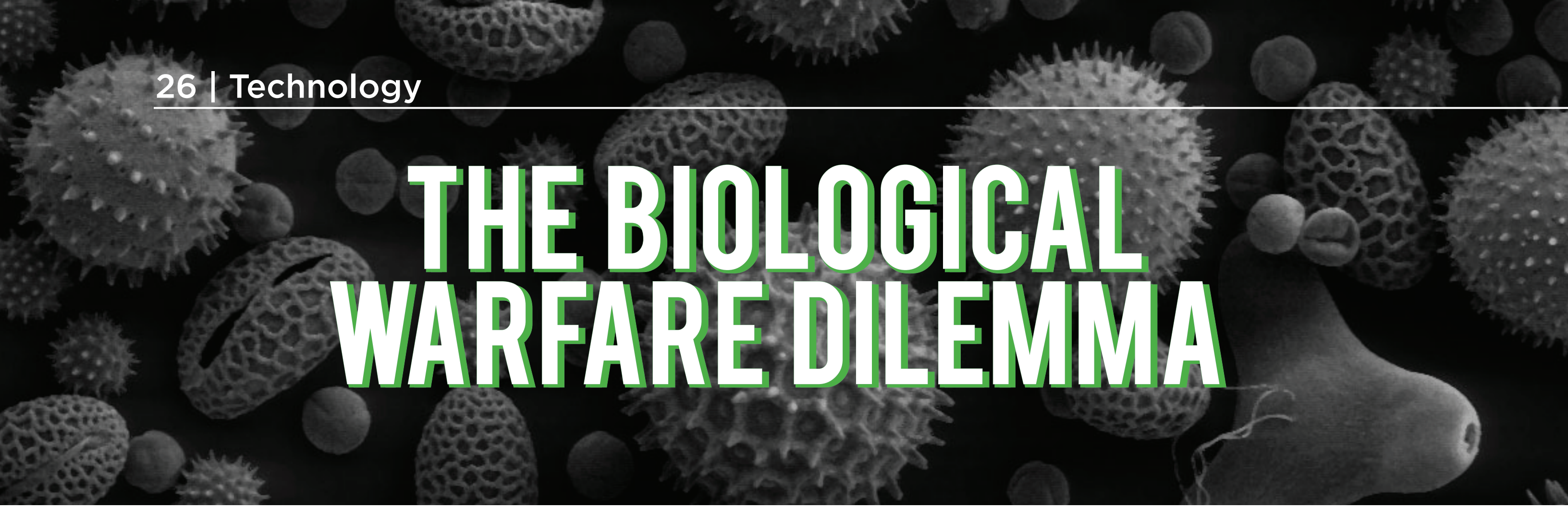
However, having to control each individual bee would be nearly impossible to implement. In order to remedy this, engineers have developed autonomous robotic bees. In March of 2018, Walmart, looking to protect their booming grocery sales, filed a patent for the development of a robotic bee that would sense the environment around them and pollinate flowers without human control. If this technology proves to be effective, these bees would be able to pollinate more than an entire crop field with great efficiency.

But, the question still remains whether robotic bees are a suitable replacement for real bees. Are these robotic bees economically reasonable? What do they imply about our values for maintaining biodiversity? What effect would the robotic bees have on the environment? These questions suggest that there are still many unknowns before these bees are sent to the flower fields. So for now, “Black Mirror” is not yet becoming a reality, and we must continue to work toward the recovery of the bee population.

Save the bees!

Science of the Total Environment (2018). DOI: 10.1016/jscitotenv.2018.06.114
Chem (2017). DOI:10.1016/j.chempr.2017.01.012

DESIGN BY KRISTI BUI, COMPUTER SCIENCE, 2021

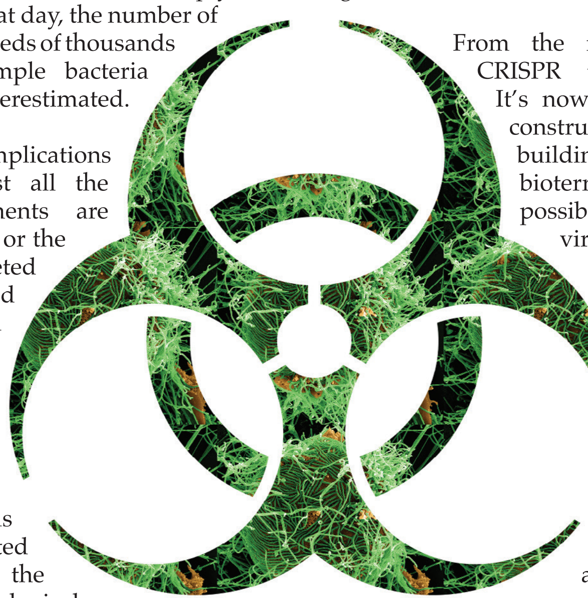


THE BIOLOGICAL WARFARE DILEMMA

BY BEIYU (PAM) LIN, BIOLOGY, 2021

DESIGN BY MARISSA KEESEY, ELECTRICAL ENGINEERING, 2022

The year was 1979, and approximately 850 miles east of Moscow, the Soviet city of Sverdlovsk was faced with somewhat of an unusual attack. It seemed as if an anthrax outbreak had occurred, with the Soviet government claiming the culprit to be infested meat. What the rest of the world was unaware of was that the Soviet Union had secretly been expanding its production of biological weapons, through a program known as Biopreparat, since the international prohibition of their use, production, and development at the Biological Weapons Convention (BWC) in 1972. Workers at the military facility that housed the program had forgotten to replace a filter, accidentally releasing anthrax spores and killing 66 individuals. If the wind had simply been blowing in the other direction that day, the number of casualties could have been hundreds of thousands instead. The power of a simple bacteria should certainly not be underestimated.



Fast forward to 2019 and the implications of biological warfare amongst all the new technological advancements are catastrophic. Biological warfare, or the use of microbes to attack a targeted population, has been a tool used by societies since the colonial period. In that era, Polish armies fired the saliva of rabid dogs at enemy camps and Russian troops catapulted cadavers of plague victims. However, the rise of gene editing in the present day has upped the threat of this ancient tool to an unprecedented level far past the levels in the 1600s, with synthetic biological weapons thought to be on the horizon.

The technique at the center of it all is CRISPR, or clustered regularly interspaced palindromic repeats: a gene editing tool that has the potential to catalyze synthetic biological weapons to uncharted territory. CRISPR technology allows scientists to alter genomic DNA, meaning that the ability to create calamitously destructive pathogens is already sitting in the hands of the scientific community.

The CRISPR gene-editing complex stems from mechanisms originally discovered through bacterial study. CRISPR is actually segments of the bacterial genome that consist of repeat nucleic acid sequences. Bacteria have an innate immunity towards bacteriophages, which are viruses that inject their own genome into a target bacteria in order to infect it. Assuming that a bacteria survives an initial encounter with the specific virus, it can incorporate some of that viral DNA into those repeat sequences as a "mug-shot" in preparation for another attack. The bacteria will then create guide RNA from these "mug-shot" sequences, which can trigger a Cas9 enzyme to cut the actual viral DNA when faced with the same invader again. Scientists have capitalized on this specific mechanism, using many of the same enzymes and aspects of the natural bacterial pathway, to create a complex that allows us to essentially edit the genomes of both humans and potential bacterial weapons.

From the initial discovery within bacteria, CRISPR technology has only expanded. It's now relatively easy for researchers to construct organisms from simple DNA building blocks and public sequences. For bioterrorism, this means that it is now possible to reconstruct known pathogenic viral or bacterial strains that currently only exist in controlled laboratory settings or to enhance ones already present in nature. Taking it one step further, researchers hypothesize that CRISPR could also potentially be used to alter the effectiveness of the human immune system in the future. The CRISPR system is heritable, meaning that it could even decrease an entire population's ability to fight off disease.

While none of these are possible yet, it's only natural to ponder the implications of this ever-growing technology. Biological weapons are currently banned internationally; however, the possibility of bioterrorists scavenging the necessary materials in order to attack a nation don't seem too offbeat. When addressing the situation, the Department of Defense and National Academy of Science stress the importance of public health measures in being able to recognize a genetically-modified pathogen. It remains impossible to create a cure for a bioweapon that doesn't yet exist; however, the institutions in charge believe that surveillance of the situation will prepare a nation as best as it can. The future of biological warfare is nearing and the best we can do is be ready.

PHOTO BY WIKIPEDIA

Ever thought about the way medications are made? A chemical plant, laden with stainless-steel columns; endless, snaking pipes and voluminous reactors, producing vast quantities of drugs — pharmaceuticals are largely mass-produced in this manner. But what if these incredibly complex molecules could be made on a small-scale, anytime and anywhere in the world?

FARMING PHARMACEUTICALS:

A SMALL-SCALE SOLUTION TO THE INDUSTRY'S BIG PROBLEM

BY CAMERON YOUNG, CHEMICAL ENGINEERING, 2021

GRAPHIC BY PIXABAY

A team of chemists from the University of Glasgow in Scotland recently announced the success of their robotic, chemical printer, or "chemputer," which was able to accurately synthesize three mass-produced drugs at a lightning pace. The machine looks like any organic chemistry student's worst nightmare, comprised of many flasks, tubes, valves, distillation columns, and micro-reactors, which allow it to perform infinite combinations of controlled, chemical processes. Through instruction by a central processing unit, or "chempiler," the device is theoretically able to replicate the synthesis of any organic molecule. Additionally, recipes can be saved, shared, and replicated by others through the use of a universal chemical language. Computer puns aside, this device could prove to be a major innovation in the pharmaceutical industry and revolutionize rural health care.

The organic synthesis of drugs is currently one of the most expensive and labor-intensive processes in manufacturing. Often, pharmaceuticals are produced in large, batch processes that result in costly excess products, unused reagents, and gallons of waste. By controlling these syntheses on a finite scale, the "chemputer" promises to reduce waste produced by large-scale operations, providing consumers with personalized dosages in exact amounts.

In a clinical setting, the "chemputer" could dramatically alter medicine across the globe. Frequently, doctors in rural areas have a very limited selection of pharmaceuticals, without access to ones which may be necessary for treating their patients. With this new device and access to an open source library of recipes, clinicians could print the exact drug in the amount required anytime or anywhere in the world.

Although this device is still in the prototype phase, results are promising. But with every success comes a new challenge: finding a way to scale up production and distribute the device across the globe, changing the way pharmaceuticals are produced for good.

American Association for the Advancement of Science (2018). DOI: 10.1126/science.aav2211

MONITORING FROM ABOVE:

How NASA's ARIA program aids in fighting California's wildfires

BY CAITY FORGEY, BEHAVIORAL NEUROSCIENCE, 2020

PHOTO BY PIXABAY

Throughout the summer and early fall months of 2018, wildfires ravaged through over one million acres of California land. The two main wildfires were the Woolsey Fire and the Camp Fire, which devastated the Los Angeles area and the northern California area, respectively. According to the California Department of Forestry and Fire Protection and the United States Forest Service annual event statistics, this fire season was the deadliest on record, with 104 known deaths, six of whom were firefighters. The Camp Fire, which made headlines when it demolished the majority of the town of Paradise, is considered the deadliest and most destructive wildfire in the entire history of California. With the intention of helping to control the reach of wildfires and other natural disasters, California Institute of Technology partnered with the NASA Jet Propulsion Laboratory to develop the Advanced Rapid Imaging and Analysis program (ARIA).

> "This fire season was the deadliest on record, with 104 known deaths, 6 of whom were firefighters."

ARIA gathers information from satellites to gauge changes in the Earth's surface. These surface changes are used to create maps of areas being affected by natural disasters that can be updated almost instantly to reflect real-time changes. The program works by gathering information using GPS and synthetic aperture radar (SAR) from satellites already in orbit. ARIA compiles and processes this information to create maps that highlight surface changes in warm scale colors. Areas highlighted in yellow show mild changes, orange show moderate changes, and red show extreme changes. These maps are used to plan relief efforts for a number of natural disasters from hurricanes and earthquakes to volcanic explosions and even wildfires.

When the California wildfires were raging out of control, ARIA stepped in to help monitor the spread of the wildfires throughout the northern California and Los Angeles areas. Based on the satellite images and damage maps provided by ARIA, the areas with the most property damage or loss of wildlife and areas at high risk of damage were identified. With ARIA's help, firefighters and volunteers were able to focus their efforts on these areas to save as many lives and acres as possible.

DESIGN BY YECHAN YANG, PSYCHOLOGY, 2022

EMBRYOS HEARD ROUND THE WORLD

A timeline of the infamous CRISPR babies

WRITTEN AND DESIGNED BY SAGE WESENBERG, BIOLOGY & JOURNALISM, 2019

In China, there are more than 820,000 people living with HIV or AIDS. In 2018, the country saw a 14 percent increase in the number of citizens with the disease. Discrimination against HIV/AIDS causes job loss, isolation, and sometimes even forced sterility.

He Jiankui, a Chinese biophysicist and former professor of biology at the Southern University of Science and Technology (SUSTech) in Shenzhen, China, recognized this problem and believed he came up with a solution using CRISPR-Cas9 gene editing technology.

In late November 2018, He announced that he had successfully gene-edited the embryos of two twins using in vitro fertilization and CRISPR techniques. Their father is HIV positive, indicating its presence in the twins' genome. He edited their genomes in order to protect them from HIV by disabling CCR5, the gene that normally acts as a doorway for HIV to enter into a cell.

Previously, humans have only had genes edited as adults in the hopes to treat deadly diseases like blood disorders, cystic fibrosis, and other hereditary illnesses. Gene editing embryos lends cause for concern since the modifications made in an embryo can be inherited by future offspring and have several risks, many of which are still unknown. The announcement that two healthy twin girls had been born genetically modified in an attempt to protect them from HIV, a disease treatable by other more affordable methods, therefore sparked worldwide controversy.

To understand how this controversy came to be and where we begin this conversation, follow the timeline below.

JUNE 2016

He's research on gene-editing embryos to protect them from HIV infection began despite the fact that there are alternative and more accessible ways to treat the disease.

MARCH 2017 – NOV. 2018

The experiments were carried out with eight volunteer couples, unbeknownst to SUSTech or government officials.

NOV. 25, 2018

He announced the birth of the first ever genetically edited babies, the twin girls, sparking shocked responses from scientists and ethicists around the globe.

NOV. 26

SUSTech published a statement that He had been on unpaid leave since February 2018, his research was not affiliated with the university, and it violated their academic ethics and codes of conduct.

NOV. 28

He presented his research at the Second International Summit on Human Genome Editing in Hong Kong. He stated that he was proud of his work and that another pregnancy of a gene-edited embryo was underway.

NOV. 29

Chinese Vice Minister of Science and Technology, Xu Nanping, announced the suspension of He's research and ordered for an investigation to be conducted into He and his team's actions. They stated that no similar research should be attempted. He was scheduled for another presentation at the summit, but it was later cancelled.

DEC. 1

He was allegedly brought back to Shenzhen and placed under house arrest.

DEC. 26

He was seen at a university guest house with his wife and child in Shenzhen, China, guarded by at least a dozen officials.

JAN. 7, 2019

The Telegraph reported possible charges of corruption and bribery, which in China can be punishable by the death penalty.

JAN. 21

The Chinese government released preliminary investigation results stating that He violated several laws in pursuit of fame and fortune, including having "avoided supervision, faked an ethical review, and used potentially unsafe and ineffective gene-editing methods on the embryos."

For more on why this study was so controversial, read *When science challenges ethics* on page 29.

WHEN SCIENCE CHALLENGES ETHICS:
Understanding the controversy behind the CRISPR babies

BY NATALIA CHAVEZ, CELL & MOLECULAR BIOLOGY, 2021

DESIGN BY KATIE GREEN, BIOENGINEERING, 2021

This past November, Chinese scientist He Jiankui announced the success of his most shocking endeavor: his lab had finally created the world's first genetically modified babies with none other than CRISPR itself. Despite its discovery in the 1980s, this hairpin-shaped DNA sequence has been controlled by researchers regarding its capability of changing gene sequences. Through countless experiments, researchers revealed how CRISPR was pursued for medical advancement; so why, when faced with the perfect opportunity for human enhancement, do people wince at the mere thought of it? These babies, two girls by the names of Lulu and Nana, give way to a promising future to a world unconstrained by diseases. Thanks to He, both girls have no reason to worry about contracting HIV due to CRISPR's success in gene alteration. The issue, then, lies not in the scientific discovery itself, but in the ethics around his research. While very groundbreaking, He's work is entwined with controversy imposed not only by scientists, but the human race as a whole as we consider breaking moral boundaries for new discoveries.

> "The importance of human life begins to lie more in the hands of scientists and researchers."

In an interview with the New York Times, bioethicist William Hurlburt claimed that He always had a "long-term goal" towards this project. The reason why He focused on HIV was because of the negative societal view the infection has in China. He sought to disable the CCR5 gene, which forms a protein pathway necessary for HIV to enter a cell. In his project, fathers of the children had the virus while mothers did not. However, the aim was not to prevent the risk of transmission into the offspring, but to offer couples affected by HIV the idea of having children protected from a fate similar to theirs.

What unsettled people, though, was how ambiguous He was with his plans. Neither the Southern University of Science and Technology, where he spent most of his time teaching, nor the Harmonicare Shenzhen Women and Children's Hospital, where he researched, contained any information about his project. He did not even inform his own research partners that he was working with gene editing techniques, and there is still the question of whether or not information about the experiment was fully disclosed to trial patients themselves.

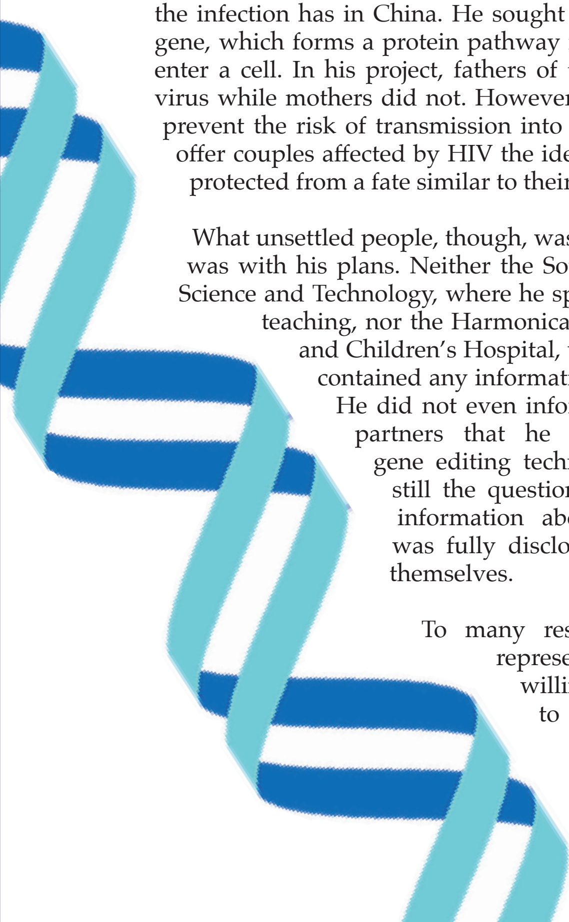
To many researchers, his work represents a disturbing willingness on his part to defy worldly ethical norms. Even leading experts, such as National Institutes of Health Director Francis Collins, admit that there is something morally wrong with He's results. The ethical problem is directed in the protection of a specific set of rules given to the realm of science that dictates what makes an experiment unethical. Indeed, He's work drills a hole into the barrier set up to keep scientists away from trifling too much with human life.

He's involvement with an embryo's genome is what sparked most controversy. Scientists are usually wary of this procedure because it leads to a potentially damaged sequence of not just the individual, but of future generations as well. It puts healthy lives at risk for no immediate benefit, particularly if it ends up changing other genes in the process. The situation essentially resembles a domino effect: in altering the genes of an embryo, those genes can expose the human to more dangerous viruses, which are then passed down to the offspring since they, too, obtain the altered genes of the parent.

Furthermore, in toying with the embryo, scientists risk their duty to respect the value of human life. This could happen particularly when it comes to the consequential destruction of embryos. If the genome editing does not go as planned, the likelihood that it would get destroyed becomes alarmingly high. The safety of a human life is too valuable to be put at risk, which is why many scientists search for alternative solutions instead. What He did was not only morally inappropriate, but uncalled for with regards to scientific advancement.

As science becomes more integrated into modern society, the decision regarding the importance of human life begins to lie more in the hands of scientists. In He's situation, people have become more aware of the hostility that exists between scientific discoveries and the norms of society. But, if He had not gone through with the experiment, someone else likely would have. After all, persuasion is the muse of science: for every new creation, there exists the need to preserve it, in fear that it will be acclaimed by somebody else.

Nature (2019). DOI: 10.1038/d41586-019-00246-2
Nature (2019). DOI: 10.1038/d41586-018-07607-3



GRAPHIC BY PIXABAY

From gravedigging to synthetic cadavers:
The future of anatomical medical training

BY ADRIANNA GRAZIANO, BIOLOGY, 2019

DESIGN BY KATIE GREEN, BIOENGINEERING, 2021

Immortal in their death, deceased human bodies provide invaluable information to physicians in training, engineers studying impact trauma, and forensic scientists investigating human decomposition. Beginning as early as 300 BC, cadaver dissections became essential to anatomical education by the 18th century. Obtained from deceased criminals and unclaimed bodies, the increasing demand for human cadavers outgrew supply and led to the immoral act of body snatching from graves during the 19th century.

Fortunately, in present day, the importance and value of cadavers has been recognized by the general public. In the United States, one of the most common sources is through body donation programs. This process involves living, informed consent that the donor's body will be used for teaching and research purposes. Body donations have been on the rise since around the 1970's, though the Anatomical Gift Association of Illinois and others reported a recent decrease in annual donations in a 2016 article with National Geographic. This decrease, pressured with a projected 29.2 percent increase in first-year medical school enrollment in the next matriculation cycle compared to 2002, has some institutions searching for alternative teaching tools.

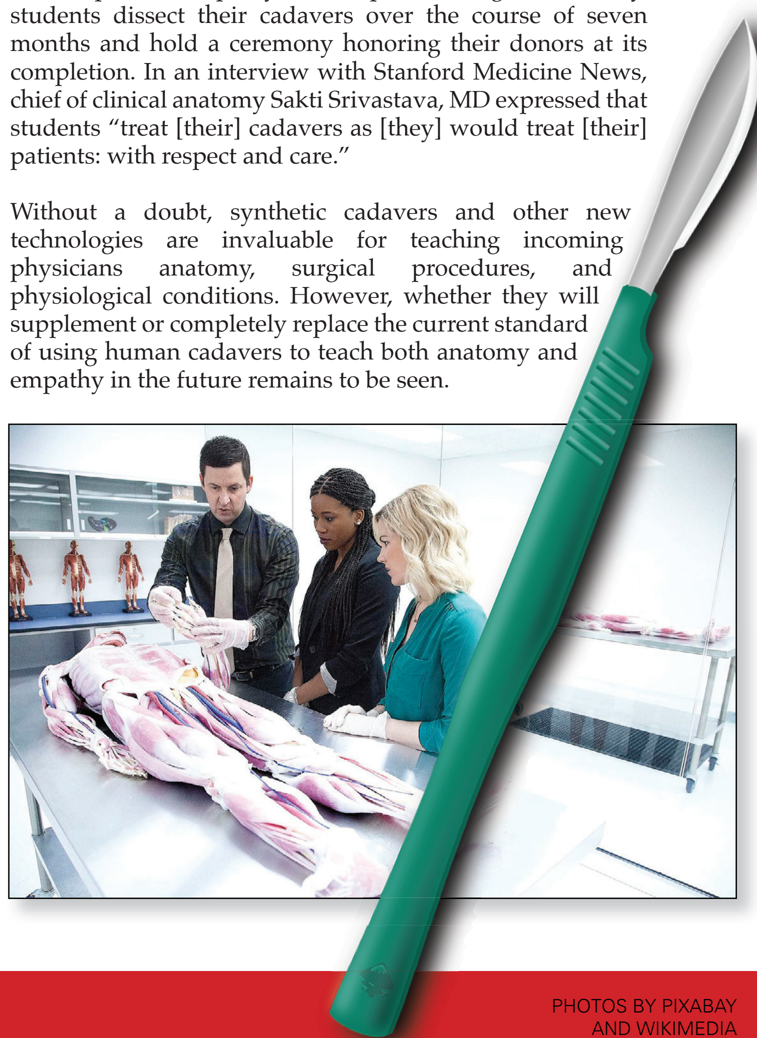
Luckily, this heightened demand has been met not with body snatching but with 21st century innovations that provide realistic technology to supply anatomical education to medical students. One visualization tool that digitalizes a real cadaver is the U.S. National Library of Medicine's Visible Human Project, dedicated to creating publicly available, cross-sectional photographs of the entire human body. Another is an interactive dissection table display named Anatomage Table, a screen on which students can visualize a digital body that can be virtually explored and dissected in 3D. For those training to be surgeons, virtual reality and 3D-printed organs are an important and realistic model to learn and practice surgery on without potentially compromising a patient.

Perhaps the most realistic of these technologies are the synthetic cadavers out of SynDaver Labs. These synthetic cadavers display all of the human body's muscles, organs, and systems in a realistic manner, both in their pliable look and moist texture. They can be used for dissection purposes or to simulate living physiologies, such as bleeding, screaming, and respiratory and cardiac arrests. Students are also able to see blood pumping through the heart in its "native" environment, an experience unmatched by standard gross anatomy. In addition to their full body cadaver models, SynDaver Labs also offers trainers for suturing, airway interventions, IV administrations, ultrasounds, and OB/GYN techniques. In an article with American Veterinarian, veterinary schools claim they're also benefiting from SynDaver's dog model because training students are able to perform important, sometimes risky surgical interventions in a realistic but safe environment.

Aside from their anatomical teachings, synthetic cadavers may be more financially realistic for some medical schools. Though human cadavers only cost $1,000–2,000 plus a delivery fee, the upkeep with the institutions they're dissected in can become costly. The formaldehyde they emit requires expensive ventilation systems that comply with U.S. Occupational Safety and Health Administration guidelines, and National Geographic reported that the University of Pennsylvania spent upwards of one million dollars to update its already in-place ventilation system. That being said, synthetic cadavers are anatomically identical as well as expensive, especially if schools want to maintain their one cadaver per every four student ratio. Their most interactive models can cost up to 100,000 dollars; yet they are reusable and can be upgraded to potentially represent anatomical variation between patients in the future.

A Clinical Anatomy study in 2018 indicated that student performance on examinations was similar between those exposed to standard cadaver dissection or alternative technological strategies. However, a genuine concern has been expressed by educators about whether solely using technology is capable of teaching future physicians what's most important: empathy for their patients. In gross anatomy, students dissect their cadavers over the course of seven months and hold a ceremony honoring their donors at its completion. In an interview with Stanford Medicine News, chief of clinical anatomy Sakti Srivastava, MD expressed that students "treat [their] cadavers as [they] would treat [their] patients: with respect and care."

Without a doubt, synthetic cadavers and other new technologies are invaluable for teaching incoming physicians anatomy, surgical procedures, and physiological conditions. However, whether they will supplement or completely replace the current standard of using human cadavers to teach both anatomy and empathy in the future remains to be seen.



Academic Medicine (2018). DOI: 10.1097ACM.0000000000002227
Clinical Anatomy (2018). DOI: 10.1002/ca.22934.

PHOTOS BY PIXABAY AND WIKIMEDIA

PLANTS IN SPACE

A farmer's guide to the galaxy

BY CHRISTINA MCCONNEY, BIOLOGY, 2021

DESIGN BY KAI GRAVEL – PUCILLO, ENVIRONMENTAL-SCIENCE, 2021

In July of 1969, the first human stepped foot on the moon. 50 years later, the first human technology has landed on the dark side of the moon. Within this span of time, numerous accomplishments have occurred in the name of space exploration: the landing of the mars rover and the establishment of the international space station, to name but a few. These great advances have unfortunately recently been fueled by a more dystopian-like agenda: exploring space to find an alternative to Earth. With the effects of global warming, man-made species extinction, and deforestation, among other issues, the race to find a second home has become ever more prevalent. However, one of the most integral parts of our world—plants—would have to travel with us through the frontier.

Growing plants in space has become an emerging area of research in recent years. In 2018, the China Spacecraft even attempted to land on the dark side of the moon, although with little success. This type of research shows particular relevance to today's world, and provides a multitude of large scale advantages to the entirety of the human race. With the expansion of space flight and exploration, scientists have been investigating ways to create sustainable environments in space—providing not only a source of vegetation but also an acting sustainable and renewable source for space dwellers.

> "With the effects of global warming, [like] man-made species extinction and deforestation, the race to find a second home becomes ever more prevalent."

Before the thought of growing plants in space can even be entertained, researchers must first work to determine how to get them there in the first place. With the knowledge that space travel pushes the human body to the extremes, new challenges arise now that an even more delicate organism is being utilized. The amount of stress that the total trip forces plants to endure causes cellular divisions and mitosis to be effectively altered, with fewer cell divisions reportedly taking place in the plants post space travel. However, after surviving these extreme stresses, plants have been known to acclimate to the new microgravity environment in two phases: first by undergoing stress responses, followed by adjusting to the constant stress through changes in metabolism and enhancing tropic responses.

Now that the plants are in space, the next step is figuring out how to grow them continuously. In 2002, a team of scientists at the University of Florida proposed a move from algae-based bioregenerative systems to hydroponic systems. The team explained how this would eliminate the problems that arose from attempting to convert algae to useful food sources. However, although a hydroponic system would provide a way to relieve nutrient stress within the plant environment, the management of a water-based bioregenerative system comes with its own problems in a microgravity environment. One of the largest hurdles that would need to be overcome in order to effectively grow plants in microgravity environments would include being able to provide ample light for photosynthetic processes to occur. Findings from the University of Florida also reported that documented plant yields increase linearly with light, pointing to the absolute necessity of light for the success of an integrated plant based environment.

The information and findings being reported ultimately point to larger plans for the future of human life in space. Based on the findings provided from institutions such of the University of Florida, in collaboration with projects currently being headed by NASA, the possibility of growing plants in spaces is very real. However, there are quite a number of hurdles and obstacles that first must be overcome before the use of bioregenerative life forms can fully sustain a space environment. That being said, the urgency to finds ways to actively grow plant life forms in space has been fully recognized and is supplemented by active research investigations occurring.

It has been nearly 50 years since the first human walked on the moon, and 21 years since the first part of the International Space Station was sent into orbit. Human ingenuity has been urged on by the need to beat the metaphorical "timer" on earth, a direct result of the damage currently being caused by global warming. A new space race has been created, now with a twist: having a greener thumb.

PHOTO BY MUHAMMAD ELARBI

Microgravity Science and Technology (2015). DOI:10.1007/s12217-015-9428-y

Putting the CAR-T before the horse

Modifying immune cells to fight cancer

BY AMANDA ZAVALA, CELL & MOLECULAR BIOLOGY, 2020

There are currently 65,922 potential cures for cancer in clinical trials — 2,006 of which involve the use of a patient's own modified immune cells, otherwise known as immunotherapy. The principle of immunotherapy is to engineer an immune response against disease using stimuli such as antibodies, immunostimulatory cytokines, and lymphocytes. T-cell therapies are becoming increasingly popular with the success of the chimeric antigen receptor (CAR) technology, which changes a T-cell's specificity to recognize a distinct cancer-associated surface marker. There are currently two commercially available CAR-T therapies, both targeting the cell surface marker CD19 found on B-cell cancers.

The approval of the first CAR-T therapies, Kymriah from Novartis and Yescarta by Kite Pharmaceuticals, were a landmark nearly 30 years in the making. Since its inception in 1993, CAR-T therapy has been difficult to optimize and full of clinical setbacks. The choice of which antigen to target is crucial because an overexpressed target could cause T-cells to attack healthy tissue and potentially cause death by "on-target, off-tumor" events. Even with the perfect target, there's a high risk of cytokine release syndrome — where the activated T-cells overproduce cytokines and induce full-body toxicity. These toxicities are common to all CAR therapies, and continue to be a prominent hurdle in clinical trials.

Kymriah and Yescarta may have won the race, but other CARs won't be left in the dust. 261 of the registered clinical trials use CAR-T cells, some exploring different targets and cancers, and others addressing adverse events by modifying the CAR molecule to improve specificity or co-treating with antibodies to reduce toxicity. The other 1,800 immunotherapies vary even more in function. Unum Therapeutics' ACTR T-cell recognizes the conserved region of antibodies so cells can target any tumor a monoclonal antibody therapy can reach. A "BiTE" — bispecific T-cell engager — is a linker that binds to T-cells on one end and tumor antigens on the other to enhance the immune response. Even red blood cells have joined the cancer arena, with Rubius Therapeutics' RCTs genetically modified to express immunostimulatory molecules.

Historically, artificially amplifying immune responses has ranged from entirely ineffective to disastrous, but progress presses on. Cell-based immunotherapies have shown efficacy in cancer patients who haven't responded to any other treatments, and the risks become more minimal and better understood with each clinical trial. Now that the first FDA approvals have set a precedent, the process of getting these lifesaving therapies to market will only become easier.

Frontiers in Immunology (2018). DOI: 10.3389/fimmu.2018.01740
Blood (2016). DOI: 10.1182/blood-2016-04-703751
Immunology & Cell Biology (2015). DOI: 10.1038/icb.2014.93

A wrinkled graft can save you a wrinkle in time

BY REBECCA AZIR, CELL & MOLECULAR BIOLOGY, 2022

As one of the leading causes of death, cardiovascular disease requires surgical treatment in order to prevent its fatal outcomes. The disease can be caused by blockage of vessels which can lead to different organs not being able to receive proper blood flow.

To treat this condition, grafts are surgically placed in a patient to replace the damaged vascular tissue in order to redirect blood flow in an efficient way. Often times, the patient's own veins will be used to create the graft, which decreases the chances of any complications arising, however that is not always a possibility. If necessary, a synthetic graft can be placed within the patient in order to help continue blood pumping.

Unfortunately, patients who receive synthetic grafts are more likely to experience thrombosis, or the clotting of the blood, which could go on to cause other serious issues such as a heart attack. Thrombosis becomes an issue when fat and cholesterol within the blood begin to stick to the blood vessels and build up in large clumps, which can then break off and get in the way of blood properly pumping through important arteries.

In an attempt to decrease the chances of these complications arising, researchers led by a team at the University of Pittsburgh are currently looking into the impacts of having wrinkled grafts, compared to flat grafts, placed within a patient. The team has received a combination of approximately $800,000 in funding from both the National Institute of Health and the National Science Foundation to continue experimentation and fund clinical translation work.

Throughout their research, the team was able to create active chambers which mimicked the action of blood pumping through the grafts. Using this mechanism, the researchers tested flat surfaced grafts and two wrinkled grafts with different-sized waves. In addition, they also tested the grafts when they were static, not moving, and actuated, expanding and contracting.

Using the results of the cardiac simulation, the research team found that the graft with the small wrinkles that continuously expanded and contracted showed the best results. The wrinkles appeared to make it difficult for different cholesterol and fat molecules to deposit themselves within, and the constant expanding of the graft would cause a release of the molecules that had attached. These results have the potential to lead to products that can help patients suffering from cardiovascular disease and change the way this life-threatening condition is treated in the near future.

Biomaterials (2019). DOI: 10.1016/j.biomaterials.2018.11.005

DESIGN BY NEELOY BOSE, BIOENGINEERING, 2022
PHOTO BY FLICKR

Northeastern, particularly because of the university's research focus and large student population. Offered at Northeastern for the first time this semester, "Science Writing" mainly consists of undergraduate journalism majors among its approximately 20 students. Senior journalism student Drew Daylor signed up because he wants more hands-on skills to market himself in the job hunt. He is excited about getting portfolio pieces as he ponders a career in science writing, whether as a reporter or on the communications side. "I think this class is good preparation for both from what I've experienced so far," he said.

Daylor has a longstanding interest in science, dabbling in some STEM courses at Northeastern before deciding on journalism. He also appreciates having a community of friends in engineering and biotechnology who help him keep up with science news, especially with his current interest in genetic medicine: "It's a great journalistic resource to stay on top of the conversations professionals are having every day in their work life."

"Science Writing" also appeals to other majors, such as first-year biology student Sinaia Keith Lang. The emphasis on promoting scientific literacy, as well as ethical and effective reporting, led her to sign up. Though being one of few non-journalism majors can be intimidating, she said she has enjoyed the discussions on interesting scientific topics.

"I hope to use what I learned from the class to better explain the science that I geek out about to the people in my life who are more inclined towards the liberal arts," Keith Lang explained via email.

Over the first few weeks of class, Bajak has been pleased with the engaged discussion. "Between unpacking breaking news stories, long magazine features, and talking to guest speakers, we've already had a broad look survey at what science writing looks like today," he said. "We've also had really deep discussions about the roles of scientists and of journalists in society, and how we think science is portrayed in mainstream media."

As he gets feedback from this first iteration, Bajak anticipates the class will appeal to a broad range of students from different disciplines: "My hope is that it can kind of become a 50-student lecture size, approachable science writing class for everyone at Northeastern."

New class teaches students to tell stories of science

BY ERICA YEE, INFORMATION SCIENCE & JOURNALISM, 2020

When news of the so-called "CRISPR babies" created by Chinese scientists broke last November, the internet flooded with all kinds of angles and hot takes. From cable news to podcasts to scientists writing op-eds, it seemed like everyone had an opinion on the topic.

"We saw almost a sensationalist take on most of this because people were so willing to be quoted about the ethics of it. Not that the scientists wouldn't explain the science, but since they were so vocal about how morally fraught this experimentation was, they didn't explain the science efficiently," said Aleszu Bajak, a freelance science journalist and graduate programs manager at Northeastern University's School of Journalism.

Splashy headlines about the newest study results are nothing new, and media coverage often doesn't explain the science with context and nuance. A new course in the School of Journalism aims to provide a place for students to explore journalism in delivering scientific news to the general public. Taught by Bajak, "Science Writing" wants to help students become better consumers of scientific information as they report their own stories thoughtfully and ethically.

Before becoming a science journalist with bylines in The Washington Post and Nature, Bajak had a past life working in a gene therapy lab. He built viruses and injected mice for three years until deciding to pursue career paths that would expose him to other scientific fields. He landed an internship at BioTechniques, a journal for scientists on laboratory methods, where he leveraged his genetics background to write news pieces.

Bajak first prototyped a science writing class at nearby Brandeis University a few years ago. That class comprised of both undergraduate and graduate students — some of whom wanted to be science journalists, others who wanted to talk about the work their lab was doing.

"It worked really well because I spent a lot of time building it so it was approachable to any student from any science or writing background," said Bajak. He wanted to get students thinking about who communicates science to society, who controls how science is told, and who gets to tell the story of scientific advances.

The success at Brandeis led him to advocate for a similar one at

PHOTO BY GUS MUELLER

BREAKING DOWN MAKEUP

BY BRYNN VESSEY, BEHAVIORAL NEUROSCIENCE, 2019

DESIGN BY KRISTI BUI, COMPUTER SCIENCE, 2021

For many, makeup represents a daily feature of life. With thousands of different products, brands, and compositions also comes the use of synthetic chemicals. The real cost of makeup goes beyond the approximate $250,000 American women spend in their lifetimes to modify their appearances — it centers on makeup's dangerous carcinogens such as parabens, formaldehyde, coal tar, diethanolamine, and nitrosamines.

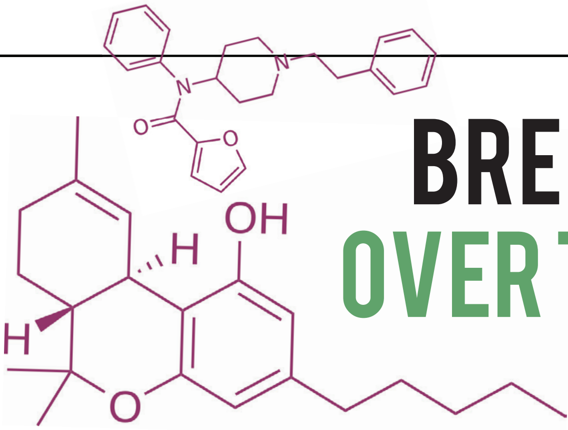
Many makeup components that are thought to be carcinogenic act as endocrine disruptors. These synthetics act as estrogen in the body, which can cause increased cell growth, decreased cell death, and metastasis. One of the most commonly known endocrine disruptors are parabens, a group of compounds used to increase the shelf life of products due to their antimicrobial properties. Parabens are added to makeup, hair products, lotions, and antiperspirants to prevent the growth of mold, yeast, and bacteria. A recent study showed more than 90 percent of people in the United States had parabens in their systems. Young children and pregnant women are the most at-risk, particularly for breast cancer, as these are the stages in life when breast tissue is most vulnerable to endocrine disruptors. Some parabens such as methylparaben have also been linked to blocking the success of chemotherapy.

Carcinogens aren't the only concern when it comes to makeup — other synthetic materials put people in danger. Polytetrafluoroethylene (PTFE), also known as Teflon, is found in many foundations, loose powders, eye shadows, and lip balms. The fluorinated compound is stable and won't break down in the environment. PTFE is generated from perfluorooctanoic acid (PFOA) and despite PTFE being the end goal, there is still a risk of PFOA remaining in the products. PFOA has been found in samples of body fluid from 99.7 percent of adults in the United States. This is an alarming statistic when considering PFOA is linked with higher rates of reproductive toxicity, delayed puberty, impacted immune responses, and cancer.

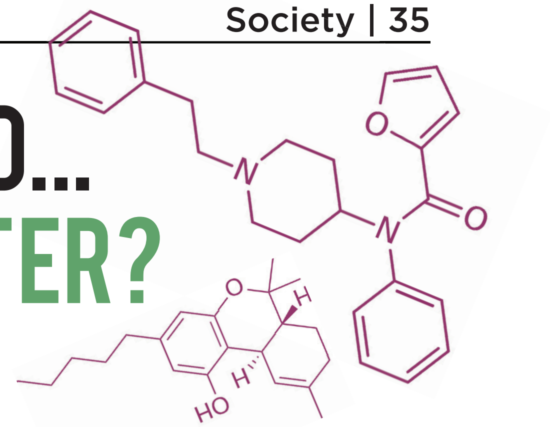
Likewise, formaldehyde in its altered form, as formalin, acts as a preservative in cosmetics. Formaldehyde is also used in manufacturing building materials and cleaning products, and side effects include skin irritation and difficulty breathing upon inhalation or ingestion, warranting its designation as a Group 1 carcinogen. Cancer seems to be a risk factor in many cosmetics; another synthetic, triclosan, has been demonstrated to cause cancer in laboratory mice. Lab mice also showed liver fibrosis when faced with prolonged triclosan exposure. Originally developed as an antibacterial for hospitals in surgical scrubs, triclosan has found its way into consumer products like deodorant, toothpaste, and cosmetics. This chemical is also used as a pesticide.

It's tempting to place these chemicals out of mind as they're applied to the face, but there is reason for concern. While many chemicals have been limited to certain "safe" quantities, consumers are not always aware of the chemicals that exist in their cosmetics and might be risking unnecessary exposure to anything from phthalates to lead. A 2013 study by the University of California, Berkeley analyzed the metal content of 32 different lipsticks, identifying traces of aluminum, manganese, and titanium in all of the tested products, as well as lead in 75 percent of the lipsticks analyzed. Manganese can cause neurological problems, while lead affects the nervous system and has been linked to learning disabilities in children. Carcinogenic cadmium and chromium were also found in the products.

There are several organizations, including Safe Cosmetics and Breast Cancer Prevention Partners, that work to identify these synthetic chemicals in cosmetics and create guidelines around their concentration. For many, the health effects of cosmetics will not be significant enough to stop using them, which is why there are products now formulated to be free of several synthetics. Ultimately, it's up to the wisdom of the consumer to decide whether to go paraben-free, stop using products with aluminum, change brands, or risk it all for a shiny berry-stained sheen. What will be worth it for you?



BREAKING BAD...
OVER THE COUNTER?



BY DREW BODMER, PHYSICS & COMPUTER SCIENCE, 2022

DESIGN BY MARISSA KEESEY, ELECTRICAL ENGINEERING, 2022

Drugs as powerful as heroin or cocaine are being sold in gas stations and corner stores all over the world. Legally. These drugs have radically different origins from more commonly known drugs. Cocaine, marijuana, heroin, and tobacco are all derived from plants, so they must be grown, harvested, and processed to make the drug effective. Synthetic drugs are not derived from plants. Instead, they are created in labs, which is why they are considered “synthetic”. They are often significantly cheaper to make than plant-derived alternatives, and require much less land—as they don’t need to be grown. This makes them very enticing for dealers and cartels: a lower-priced product means a larger profit margin.

According to the CDC, from 1999 to 2017, drug overdose deaths in the United States increased by 255.7 percent (6.1 to 21.7 deaths per 100,00 people). A huge portion of that number is due to synthetic drugs, especially synthetic opioids. Fentanyl is the most commonly known synthetic drug, but others have risen in popularity, going by names such as spice and K2. In July, there were almost 150 cases of K2-related illness and several deaths in Washington, D.C. in what was described on social media as a “zombie attack”. Victims of the drug were seen stumbling around in a trance-like state, drawing a lot of similarities to the TV show “The Walking Dead”. According to witnesses, the victims most likely bought the drug from a local deli around the corner from where many of the overdoses occurred.

The real beginning of the synthetic drug epidemic can be traced back to John W. Huffman, a chemist at Clemson University. Before his retirement in 2010, Huffman and his team were studying the cannabinoid receptors in mammals. They synthesized over 400 different compounds in an effort to understand the effects of the endocannabinoid system on the body. The effort was aimed at creating a less-addictive painkiller as a potential damper on the current opioid epidemic in the United States, but some of the compounds created had intense hallucinogenic effects.

All of this research was published, with each compound named JWH (after John W. Huffman) along with a number signifying the number of compounds synthesized so far. But the research had unintended effects. Some underground chemists read the paper and began synthesizing the compounds from Huffman’s research to sell online. It was JWH-18 that was first to be identified, thousands of miles away in a forensics lab in Germany. JWH-18 was being sold as “Spice” across Europe.

The biggest problem currently presented by synthetic drugs is in passing laws to control them. The process for analyzing a drug, determining medical use, danger, and potential for addiction is called “scheduling”. Scheduling a new substance is a complicated process, and is done based on the chemical formula of each psychoactive compound. Chemists have begun to take advantage of this scheduling process by changing their formulas rapidly enough that by the time a drug has been discovered and scheduled, a new, slightly different drug is available. These slight differences in chemical makeup allow a drug to come into the US unimpeded, as this new substance is not controlled. And as an added benefit for users, it will not show up on most commercial drug tests. This legal loophole allows these synthetic compounds to be sold at gas stations and corner stores, in little packets labeled “not for human consumption”.

Governments have begun to combat this variation with analog laws, which state that if a drug is found to be a close copy of a previously known illegal substance, then it is subject to the same regulations. Unfortunately, these laws have forced chemists to change their formulas more significantly in order to get around the analog laws, which can make the drugs more dangerous for users because larger changes to the recipe mean more unpredictable effects. Eventually, chemists will begin to run out of new recipes for synthetic drugs. Until then, lawmakers and white-hat chemists alike must work hard to stagnate this growing epidemic.

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Celebrating NU SCI 10 YEARS

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