June 2024

SCIENCE CURRENTS

ELECTRIFYING MINDS

On the heels of the successful launch of the first MHS Science Currents *earlier this spring, we are truly excited to present to you a brand-new June edition to conclude a stellar year of science at MHS. From top-notch classroom instruction to detailed hands-on dissections, as well as trips to labs, focused research, and engaging lectures by scientific and medical professionals, there were so many opportunities for student growth and the enjoyment of what science has to offer. We extend our gratitude to* ***Mrs. Brenda From and Mrs. Sheila Minis*** *for all of their dedication to the field and to the students of MHS.*

I am impressed with the work of our Science Currents *contributors. This edition brings to the fore some of the most cutting-edge developments in the fields of medicine, the environment, and technology. The students' writing also confronts us with tough questions which must be answered in the near future if we are to not only thrive, but also survive. What are the ethical dilemmas associated with AI and LLMs turning thought into text? What would our individual, familial, social, communal, and even national and international existences be like if indeed we could all read each other's minds? What are the benefits and risks of deep brain stimulation to treat depression? Can something we usually think of as harmful, such as bacteria, be effectively used to rid the environment of dangerous toxins?*

I am also pondering a lesson I gleaned from Danielle Mandelbaum's article on Lyme disease: When looking at a challenge or problem, remember to take a step back to explore not only the immediate situation or even the most recent cause, but at what may have occurred even farther back than that. If you can change a variable at an earlier stage, your final result may be quite different.
What are the variables we can change to yield our best future?

Have a thoughtful and enjoyable summer!

Mrs. Nechama Mirsky
Principal, General Studies

Positive Thoughts Only

Chani Manela ('25)

Depression is a worldwide issue that affects hundreds of millions of people throughout their lifetime. Many attempts to treat depression using medications such as antidepressants or other approaches such as talk therapy or electroconvulsive therapy don't yield satisfactory results for many people. Millions find themselves trapped in the same pattern and begin believing that they have "treatment-resistant depression" or "intractable depression." However, recent studies are introducing a new treatment plan for severe depression known as deep brain stimulation (DBS).

Deep brain stimulation is a highly experimental and invasive brain surgery, requiring holes to be drilled into the skull in order to place electrodes deep in the brain. In DBS, surgeons put thin wires with electrodes at the end into certain parts of the brain through small holes in the skull. These wires are then connected to a small battery-powered device implanted under the skin near the collarbone. During and subsequently after the surgery, small electrical impulses are sent into the patient's brain through these electrodes. However, it is unknown how these small impulses change the messages that move between different regions of the brain.

The ultimate goal is that these electrical impulses will attempt to reset brains that are controlled by psychiatric disorders, including depression. This experimental surgery will give people suffering from all different kinds of disorders a new chance at life and the opportunity to make the most out of it.

Depression is a constant, unrelenting struggle for some people; many ultimately can't pull through and end up taking their own lives to be free of their pain. An estimated 50,000 people a year die by suicide and 60% of those suffered from major depression. Depression annually takes the lives of so many from the world and is the leading cause for suicide.

In Deep Brain Stimulation (DBS) electrodes are placed deep in the brain.

(Continued on page 2)

A Natural Clean Up Crew

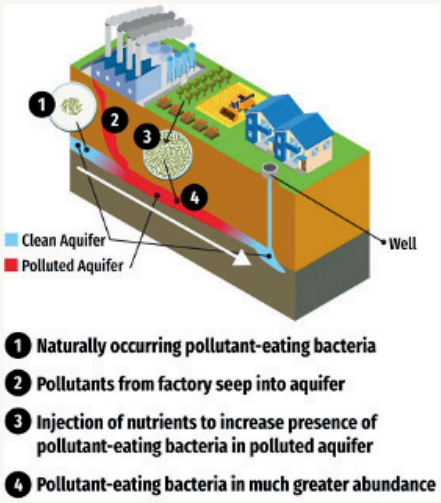
Rivky Lamm ('26)

Recently, chemical and environmental engineers at the University of California, Riverside discovered two types of bacteria that are capable of breaking down per- and poly- fluoroalkyl substances (PFAS). Due to their strong carbon-fluorine bonds, PFAS are dubbed "forever chemicals" because they stubbornly persist in the environment for decades or longer. Their toxicity is well documented in literature. These forever chemicals are used to make a film coating that causes products to become heat, oil, stain, and water resistant.

The two strains of bacteria recently discovered, Desulfovibrio aminophilus and Sporomusa sphaeroides, are capable of breaking down the forever chemicals. They first break up the chlorine to carbon bonds, generating temporary unstable molecular intermediates. The fluorine is subsequently released, destroying the pollutant's structure. These bacteria are naturally found underground, including in places where the water supply is contaminated by PFAS. To clean the water, affordable nutrients like methanol could be added to the groundwater which would cause the bacteria population to increase and dissolve the chemicals. Previously, microbes have been used to clean up oil spills so it is not surprising that other microorganisms have different capabilities to remediate the environment.

This discovery is very significant because it can greatly impact our ability to deal with polluted waters in a natural and inexpensive way. A person might think that issues with contaminated water only apply to third world countries; but the water crisis in Flint, Michigan showed us otherwise. After years in which the residents of Flint, Michigan have been contending with lead contamination, high levels of PFAS have been detected in the city's water supply, originating from General Motors facilities in the area. It is clear how important it is to have reliable and accessible methods for cleaning groundwater even here in the US. As the image below demonstrates, the bacteria could be cultivated to clean water in areas between factories that release contaminants and wells that provide essential drinking water for people and animals.

Next time you drink clean water from the tap, give these hardworking beneficial bacteria a round of applause.



This article is adapted from: "Calorie Restriction in Humans Builds Strong Muscle and Stimulates Healthy Aging Genes." National Institutes of Health, U.S. Department of Health and Human Services, 13 Oct. 2023, www.nih.gov/news-events/news-releases/calorie-restriction-humans-builds-strong-muscle-stimulates-healthy-aging-genes.

Positive Thoughts Only (Continued from page 1)

It is estimated that the suicide risk for someone with mental illness, such as depression is about 5% - 8%. Depression also leads people to develop other problems such as alcoholism; along with potentially ruining their own lives, these problems can affect the lives of their families and friends as well.

Through introducing DBS as a successful way to treat depression, it will lend people newfound hope and the ability to reimagine a future for themselves, where they are able to live a happy, joyful life. Deep Brain Stimulation is a transformational surgery and can truly benefit the population and allow people a second chance at their lives. More testing and clinical trials will allow extensive research into this development, and hopefully, usher in a new time, where depression and suicide rates decrease and the world is a happier place all around.

This article is adapted from:
Sanders, Laura. "How Brain Implants Are Treating Depression." Science News, 21 Sept. 2023, www.sciencenews.org/article/brain-implant-depression-electrode-stimulation-surgery.

Unlocking The Path To Tomorrow's Cures

Chaya Schwartz (‘26)

Every person's lungs are different. This causes lung or respiratory diseases to affect everyone differently. In addition, everyone experiences different environmental factors. Therefore,when doctors are trying to study and map out a treatment and possible cure for a disease, there are many complex factors. By studying the exact same tissues and cells, scientists are able to unambiguously follow the route the disease takes for infection spread and study preventive measures.

Scientists from the Rockefeller University took human stem cells and grew genetically identical lung buds on microchips, which then grew into mini lungs. They can produce these exact mini lungs many thousands of times, which allows them to track thousands of infectious diseases at once, without any genetic and environmental variables that interfere with the study and its results. These mini lungs all have the same DNA sequence, which allows scientists to study the disease path, as well as potential cures for the disease, more easily.

Stem cells have the ability to infinitely divide and create more stem cells. However they can’t form a specific organ on their own. They need to be in a confined space, and need to be given specific stimuli in order to grow into a specific organ. The signals that push the stem cells to form specific organs come from four main signaling paths. In order to create the mini lungs scientists used KGF (keratinocyte of growth factor) and BMP4 (bone morphogenetic protein 4). Both of these chemical signals contribute to the cell differentiation and growth of the mini lungs.

When scientists studied Covid (caused by the virus SARS-Co-V2) in the lung buds and in lung tissue of people who have died from Covid, they found that by blocking the BMP pathway, the cells were less vulnerable to being infected with Covid. By studying mini lungs, scientists were also able to find which part of the lungs the Covid virus affects most. They found that the alveoli sacks were affected more than the airway passages.

Through the use of the mini lungs, the researchers can quickly develop new vaccines, study many other respiratory diseases and test new drugs as possible therapeutics for these diseases. This technique of creating mini lungs can be applied to other organs and tissues, for instance the brain,to study other devastating diseases and find cures.

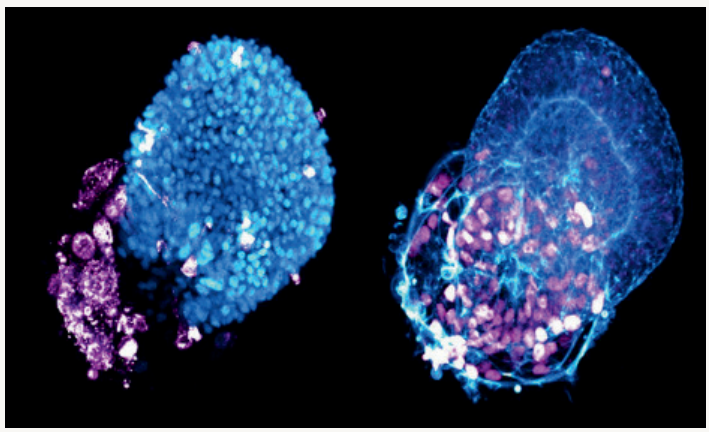


Photo of the mini lungs - the purple is covid virus attacking the alveoli and airway tissues (the blue) of the mini lung

This article is adapted from

“Lab-Grown Mini Lungs Could Accelerate the Study of Respiratory Diseases.” The Rockefeller University Science News, 30 May 2023, www.rockefeller.edu/news/34104-lab-grown-mini-lungs-could-accelerate-the-study-of-respiratory-diseases/.

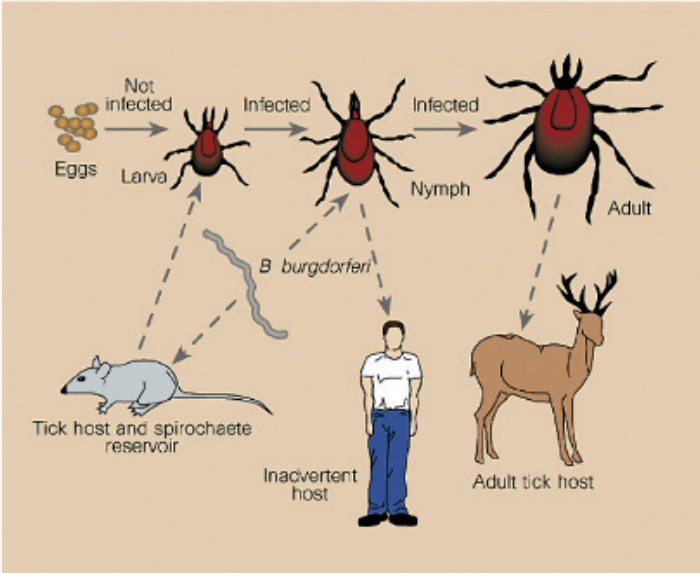
Eradicating Lyme Disease, One Mouse at a Time

Danielle Mandelbaum ('25)

Every year 476,000 people contract Lyme disease. This past summer, I was one of them. Baruch Hashem, It did not affect me at all except for the two rounds of antibiotics I took to get rid of it. Unfortunately, many are not as lucky. Side effects of Lyme disease can show up later in life, and include impairments in cognition, memory, fatigue, and pain. A primary carrier of Lyme disease is the common mouse. Ticks transmit Lyme disease to these mice, who then transfer it to humans.
A new edible pill might stop these transmissions in their tracks.

A rodent sized injection, although comical, is not the method of choice for these scientists. Instead, nutritionally void pellets are covered with the vaccine, which the mice then eat. Just like the flu shot you get at the doctors office, these pellets are like a shot to help the mice develop antibodies, which are proteins in mammalian blood that fight specific toxic substances by neutralizing or destroying them. These antibodies specifically target the bacteria Borrelia burgdorferi, which is responsible for most cases of Lyme disease in the U.S. The antibodies bind a protein called OspA that can be found on the surface of the bacterium, thus blocking its ability to infect ticks (while they feed on the blood of an infected mouse).

So why are scientists vaccinating rodents and not humans? The idea is that if the mice, the most important hosts of this disease, are protected against Lyme, they won't transmit it to ticks that might spread it to humans or other animals.



Life cycle of the tick vectors for the Lyme-causing bacteria - B. burgdorferi: Reservoir hosts, such as mice, transmit the bacteria to the larva or nymph stages of the tick when they take a blood meal. The spirochetes are then transmitted by infected nymphs or adult ticks to other reservoir hosts and to humans, which are inadvertent hosts (incidental host or a non-specific hosts). Deer are important hosts for adult ticks, but they are not effective reservoirs for the bacteria that causes Lyme disease.

This vaccine has proved to be somewhat effective in reducing the amount of B. burgdorferi infected ticks, as after two years, there was a 30% reduction rate of infected ticks in residential areas. However, it is not yet known if arming these mice against Lyme disease will also lower the rate of Lyme in humans like it did for ticks.

Many more methods for preventing this disease are in the works. Scientists are studying whether genetically modifying mice to produce the antibody on its own will lower the rate of infection. Human vaccines are being tested on thousands of people, and studies on controlling deer population to prevent Lyme are in the works. Hopefully, Lyme disease will become a relic of the past, as scientists strive to make the world a safer place, one mouse at a time.

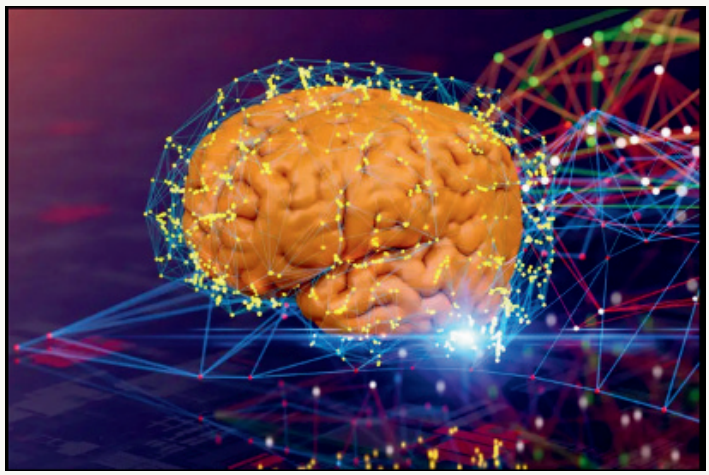
This article is adapted from:
Dzombak, Rebecca. "How a New Lyme Vaccine for Mice May Protect People." Science News, 1 June 2023, www.sciencenews.org/article/new-lyme-vaccine-mice-protect-humans.

Can You Read My Mind?

Elianna Mishaan ('25)

The discovery of artificial intelligence and its potential uses has taken the world by storm. Its possibilities are vast, offering opportunities that range from increased efficiency to breakthroughs in research, specifically scientific exploration. A new system that was recently developed records the brain's electrical activity through the scalp and can turn thoughts into words with help from a large language model (LLM). LLMs are a type of AI that is trained on large amounts of text data and uses statistical relationships to learn how to understand, translate and generate language.

The technology would work by using specialized computer systems to analyze brain activity. The doctor would start by recording brain waves using ElectroEncephaloGraphy (EEG) technique - attaching electrodes to the patient's head to measure the brainwaves - while the participantsays specific words and thinks about that specific topic. Then, these EEG recordings should be able to be converted into text. In this study, there were three women watching videos while testing it out. The programs learned to connect the videos with patterns of brain activity. Later, when the women watched more videos, the programs could predict what they were seeing based on their brain signals and were able to figure out which parts of the brain were active when processing the videos. Researchers believe that this can lead to the ability to decode thoughts, ideas and even dreams without people actually saying anything out loud.



This new AI technology has the potential to turn brain waves into written text - thereby showing what someone's thinking. While this new system is not close to perfected, its possibilities are endless. This can be extremely helpful in cases where a patient is unable to speak. For a family who has a relative who has been silenced their whole life this is a game changer. Patients can express how they're feeling and what they need when in the past, family and doctor would just have to guess. In many trauma cases, psychologists will be able to understand their patient's feelings and will be able to help work through their struggles more quickly and without requiring the patient to have the pain of reliving the situation by explaining it.

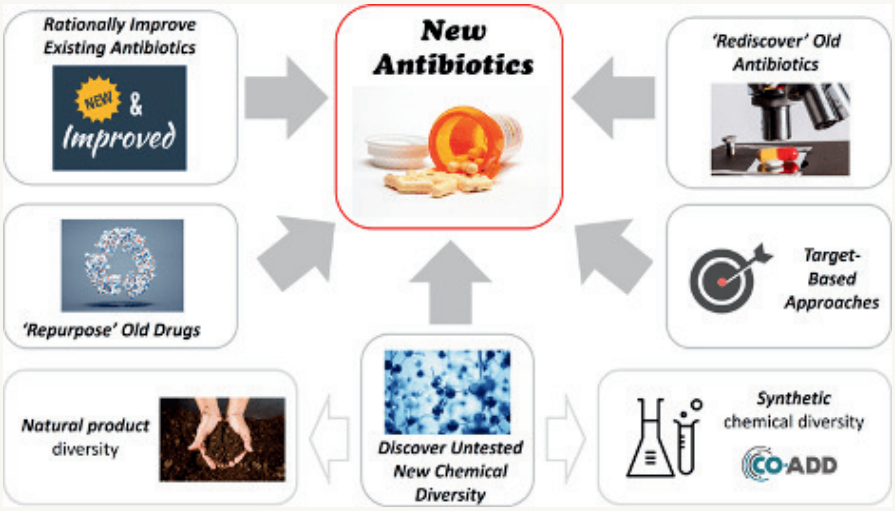
Indeed, there are many dangers to using artificial intelligence to decode people's thoughts, such as ethical concerns of invading a person's privacy without their consent or security risks of hacking the brainwave data stored digitally. Nevertheless, there are so many benefits, and this research can be the start of helping many people who in the past did not have an opportunity.

This article is adapted from:
Woodford, James. "Mind-Reading AI Can Translate Brainwaves into Written Text." New Scientist, New Scientist, 14 Dec. 2023, www.newscientist.com/article/2408019-mind-reading-ai-can-translate-brainwaves-into-written-text/.

AI: Another Weapon in the Medical Arsenal

Nechama Samet ('26)

Antibiotic resistance is a world-wide health threat, with an estimated death toll of 1.27 million people per year. This became especially acute during COVID-19, and the lack of development of new antibiotic classes or new types of antibiotics has made the situation worse. The discovery and subsequent introduction of new antibiotics by traditional methods take a long time and is prohibitively costly.



Different approaches to discover new antibiotics

In a recent development, James Collins and his team used a specific type of Artificial Intelligence (AI) called deep learning to screen an existing library of many known pharmaceuticals that exhibit antibiotic properties and find common chemical properties and structures. The AI program can then make predictions and suggestions for the synthesis of related compounds by modifying the ones that are already known but that do not have antibiotic properties, or for "drug repurposing." This exponentially speeds up the search for the "needle in the haystack." Traditional methods for new drug development can take upwards of twelve years, but with AI, bringing a drug to the animal testing stage can take a matter of days. In a matter of minutes, AI can sort through millions of potential candidates to identvify the few that would be worthy of further exploration. The next steps would include more testing for efficacy and toxicity in order to make sure the new antibiotics are safe and effective in humans. So far, the team was able to identify and test 283 promising compounds in mice, and found several that were effective against the stubbornly hard to kill pathogens MRSA (methicillin-resistant Staphylococcus areus) and vancomycin-resistant enterococci.

The goal is that AI can help create antibiotics that save lives. This discovery is crucial for the future because it provides a promising solution to the major health problem - antibiotic resistance. Antibiotics, which help fight bacteria, are not working as well as previously because the bacteria are rapidly mutating so that the antibiotics are no longer effective at destroying them. Bacterial infections are causing more deaths and the lack of antibiotics makes it harder to combat and treat these bacterial infections around the world. Using AI to discover new medicines is a game changer, as it allows the information to come much quicker than the usual methods. The discovery not only deals with the serious problem of resistant bacteria but also shows how artificial intelligence can change the way we develop and use medicine. AI ranks up there in the medical tool-chest with advances in imaging, genomic analysis and organoid culturing. It gives us hope for finding better and faster solutions to health problems in the future.

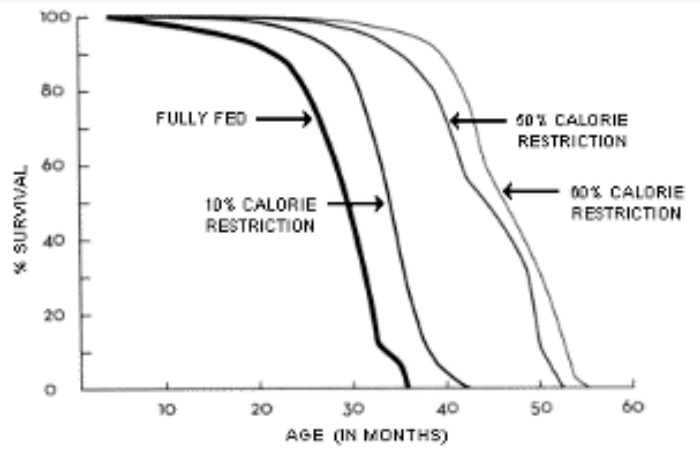
This article is adapted from:
Lewis, Tanya. "New Class of Antibiotics Discovered Using AI." Scientific American, 20 Feb. 2024, www.scientificamerican.com/article/new-class-of-antibiotics-discovered-using-ai/.

Caloric Restriction and Healthy Aging

Tehila Simai ('26)

***This article is not intended to encourage calorie reduction; nutritional decisions should be made in consultation with a nutrition professional.*

In a groundbreaking study, researchers at the National Institutes of Health (NIH) have shed light on the transformative effects of moderate calorie restriction on muscle rejuvenation and essential biological pathways associated with overall health. This investigation, conducted as part of the Comprehensive Assessment of Long-Term Effects of Reducing Intake of Energy (CALERIE), aimed to bridge the gap between animal studies (see graph below) demonstrating the benefits of calorie restriction and its potential applications in humans.



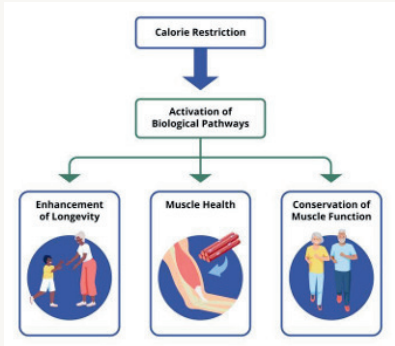
Despite participants falling short of the intended 25% reduction, even achieving a still significant 12% decrease in daily caloric intake proved sufficient to activate key biological pathways linked to healthy aging, underscoring its potential to make a substantial difference in health outcomes.

The study delved into the molecular underpinnings of the observed benefits by analyzing thigh muscle biopsies from CALERIE participants. While muscle mass understandably did decrease, surprisingly muscle strength did not; on a per gram basis, muscle strength actually increased. Results showed that calorie restriction influenced human genes in a manner similar to findings in animal studies. This included increasing expression of genes responsible for energy generation and metabolism, alongside decreasing the expression of inflammatory genes, leading to a notable reduction in inflammation.

The significance of this research lies in its potential to mitigate age-related diseases by addressing the pro-inflammatory state associated with aging. The interconnectedness of inflammation and aging posits that even a modest reduction in calorie intake should be a key strategy for promoting healthy aging.

Looking forward, this study opens avenues for further exploration into the benefits of calorie restriction on human health. Its findings may shape future strategies for wellness promotion and age-related disease prevention, providing invaluable insights for researchers and the broader population alike. As scientific understanding advances, this study contributes essential information that could influence lifestyle recommendations and dietary practices, offering a pathway to enhanced health and longevity.

In conclusion, the NIH's research shows that eating fewer calories, but not too little, can help activate important biological processes and contribute to aging more healthily. This study not only emphasizes the practicality of a modest reduction in calorie intake but also positions it as a powerful and accessible approach to fostering overall well-being in the aging population.



This article is adapted from:

"Calorie Restriction in Humans Builds Strong Muscle and Stimulates Healthy Aging Genes." National Institutes of Health, U.S. Department of Health and Human Services, 13 Oct. 2023, www.nih.gov/news-events/news-releases/calorie-restriction-humans-builds-strong-muscle-stimulates-healthy-aging-genes.

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