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ANTIDOTE

UNLOCKING YOUR INNER GENIUS
A THERAPEUTIC SIDE TO OXYGEN
ENGINEERING THE NEXT HUMAN GENERATION

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LETTER FROM THE EDITOR

Antidote: a medicine taken or given to counteract a particular poison; something that counteracts or neutralizes an unpleasant feeling or situation.

This is the dictionary definition of antidote, but the term can be expanded to any form of problem solving, or any new idea that has the potential to solve a particular issue. Consequently, many of the articles in Issue 24 of NUScience discuss concepts that may serve as the antidote for a problem, whether it's the potential for distraction to fuel creativity or the possibility of "engineering the next human generation" through gene-editing technology.

Other articles dig deeper into problems that may in the future require an antidote – like the poorly financed medical protocols in Argentina – or bring up new issues that haven't been discussed before, like the potential for serious megadroughts in the U.S. Southwest and Central Plains.

Regardless of article topics, "antidote" seems like an appropriate theme for this issue, as finals are nearing their close and many students are at the height of their stress. Whether you picked up this magazine because a particular article title caught your eye, or you spotted your friend's name, or you simply want to take a moment to distract yourself, I hope that this issue provides the "antidote" to your need.

Sincerely,

Gwen Schanker
Editor-in-Chief
Biology and Journalism, 2018

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IN THIS ISSUE



5

A Therapeutic Side to Oxygen

Eliciting antitumor immune responses

8

Engineering the Next Human Generation

The power of gene editing

18

Distractions: Fueling Your Inner Genius?

The relationship between attention and creativity



22

Discovery of Massive Black Hole Baffles Scientists

Prodigious. Colossal. Behemothic.



Read more at
nuscimag.com

14

Deep Sea Hydrothermal Vents

New drug discoveries under the sea?

6

Mindful Mouthful

Are the language and motor systems connected?

17

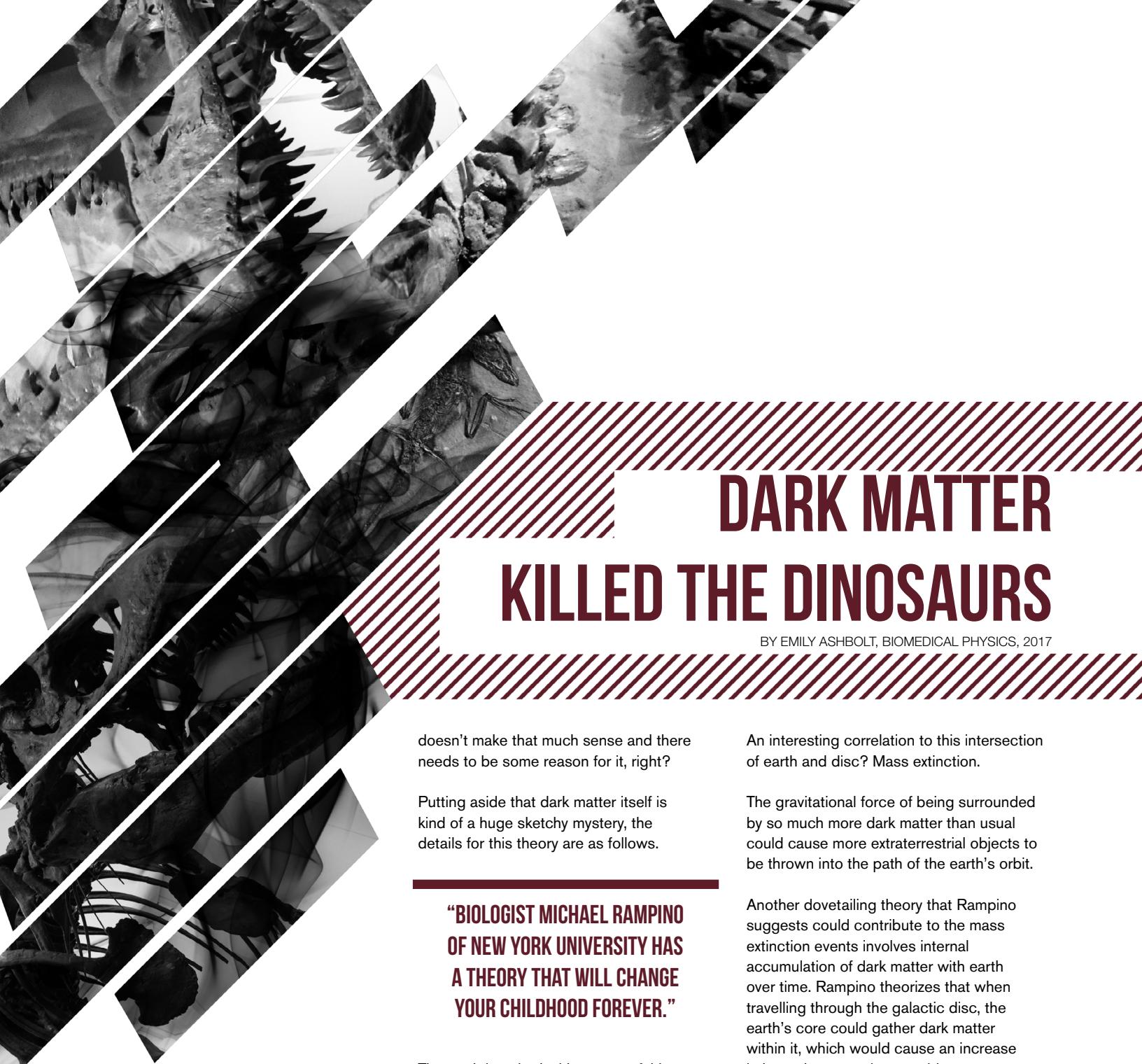
Megadroughts: The Dry and Dusty Future

Analyzing the risk of severe droughts

24

Nature Always Finds a Way

Inspecting the propagation of the Dengue Virus



DARK MATTER KILLED THE DINOSAURS

BY EMILY ASHBOLT, BIOMEDICAL PHYSICS, 2017

doesn't make that much sense and there needs to be some reason for it, right?

Putting aside that dark matter itself is kind of a huge sketchy mystery, the details for this theory are as follows.

"BIOLOGIST MICHAEL RAMPINO OF NEW YORK UNIVERSITY HAS A THEORY THAT WILL CHANGE YOUR CHILDHOOD FOREVER."

The earth is pelted with meteors fairly constantly, but there is a cyclical element of the intensity that follows a pattern of about 30 million years. This kind of pattern corresponds with the orbit of the earth going up and down through a zone containing a theorized "galactic disc," a plane in the center of the galaxy that is speculated to contain a lot of dark matter and energy. This phenomena has been documented by theoretical physicists Lisa Randall and Matthew Reece of Harvard University, and the European Space Agency's Gaia mission is on track to confirm or deny the presence of such a disc by its completion.

An interesting correlation to this intersection of earth and disc? Mass extinction.

The gravitational force of being surrounded by so much more dark matter than usual could cause more extraterrestrial objects to be thrown into the path of the earth's orbit.

Another dovetailing theory that Rampino suggests could contribute to the mass extinction events involves internal accumulation of dark matter with earth over time. Rampino theorizes that when travelling through the galactic disc, the earth's core could gather dark matter within it, which would cause an increase in heat, that, over time, could cause volcanic eruptions, the rising of mountains, sea level changes, and even the reversal of magnetic fields. Such earth-surface disasters have been linked to many mass extinctions throughout the earth's history. Is this sound science? Not yet. With so much uncertainty in calculations, and so much unknown about the very properties of dark matter, proof is hard to come by. But to many, actual truth is less important than getting people thinking about these matters. Tyrannosaurus notwithstanding. ■

Biologist Michael Rampino of New York University has a theory that will change your childhood forever. The end of the dinosaurs, as we all know it, was a fiery, meteor-themed explosion of smoke and wailing brontosauruses. A new potential variable in all of this? Dark Matter.

Dark matter is an interesting phenomenon to pin cause on because no one actually knows what it is. Dark matter and its bosom-buddy dark energy make up an estimated 95 percent of the entire universe based on visualizations of gravitational effects and the fact that a lot of physics

*Oxford Journals: MNRAS (2014).
DOI: 10.1093/mnras/stu2708.*

A THERAPEUTIC SIDE TO OXYGEN

BY JOSHUA TIMMONS, BIOLOGY, 2017

Northeastern Professor Michail Sitkovsky, along with his former graduate student and principal investigator, Stephen Hatfield, as well as several NU undergraduate students and colleagues, raised big hopes with a deceptively simple discovery. Oxygen elicits – or more correctly, enables – an antitumor immune response.

Yes, you read that correctly: oxygen may be a potent cancer treatment one day. Imagine all the patients in oncology clinics, not just those with COPD, wheeling around their own oxygen tanks. This is the cancer-fighting future Sitkovsky may have created when he and colleagues found that oxygen rich environments promote a more robust immune response.

The immune system is in a constant state of surveillance. T cells and Natural Killer (NK) cells patrol to rid the body of mutated cells. Cells that accumulate mutations express their abnormalities on major histocompatibility complexes (MHC) outside their membranes and, in ideal circumstances, are eliminated.

In opposition to this process is adenosine. Adenosine, most often recognized as a component of ATP, plays a significant role in our body's response to damage. It surrounds areas of cellular damage to prevent the immune system from wreaking havoc on already damaged cells. It is something of a physiological stop sign.

Unfortunately, cancers abuse this relationship. In areas of low oxygen, like tumor environments, cells produce and secrete high amounts of adenosine. This shrouds the cancers and creates an immunosuppressed space where they develop and grow, with a pass from the immune system. As a result, the “adenosinergic” cloak that holds T cells and NK cells in arrest as an effective inflammatory response is thwarted. Interestingly, the reverse is true in areas of oxygen abundance (hyperoxia) in which cells produce far less adenosine.

Realizing this pattern and determined to investigate its relevance to cancer, Sitkovsky's team set out to give mice supplemental oxygen along with an immunotherapy. Years ago, peers would have scoffed at this insight.

“It was not novel to use oxygen, everyone used oxygen for a long time, but they used different assumptions,” says Sitkovsky. “We said ‘we should oxygen if, and only if, there are anti-tumor killer cells.’ Which means we must use oxygen only in combination with immunotherapies.”

His hunch proved correct: mice given melanoma, supplemental-oxygen, and an immunotherapy had a four-fold reduction in the number of melanoma metastases to the lung, relative to those without the oxygen. Further, there was a four to fivefold increase in tumor-clearing T cells at the site of the tumor and a massive increase in immune signaling: a robust tumor-clearance response. The immunotherapy “turned on” the immune system while the supplemental oxygen “lowered the gates” of the surrounding adenosine.

These results indicate that Sitkovsky, director of the New England Inflammation and Tissue Protection Institute, has given oncologists a radically simple option for cancer treatment. The side effects of oxygen, at 60 percent, are minimal, and the supply is cheap and available. And, considering the lack of need for FDA approval, this may be the quickest-to-market cancer treatment in the last half century.

“It's about maybe \$10,000 - \$20,000, but this is good. It's enough for someone to make money on it,” Sitkovsky explains.

“Without a commercial manufacturer, who will pay for it? The taxpayer? It's much cheaper for a taxpayer if a company makes it.”

The Science paper is the most recent chapter in Sitkovsky's cancer research, but it will not be the last. With the high profile paper in *Science*, and its complementary paper in the *Journal of Molecular Medicine*, oxygen has gone mainstream. In his words: “people are interested in this all over the world now.” In fact, Sitkovsky says he's received interest from scientists, physicians, and patients alike. Compared to proton therapy, genetic engineering, or invasive surgery, supplemental oxygen is relatively tame.

As cancer immunologists continue to investigate and develop immune-based therapies in the years ahead, oxygen may become ubiquitous in oncological standard of care. “There are three types of immunotherapy. Supplemental oxygen works with all of them.”

Time will tell to what extent Sitkovsky's findings breathe air into cancer research. “We provided proof of principle. We showed them, ‘this is how it's done.’”

If you'd like to learn more about cancer immunology directly from Prof. Sitkovsky, he teaches an immunotherapy seminar at Northeastern every Spring. ■

Sci Transl Med (2015). DOI: 10.1126/scitranslmed.aaa1260.





MINDFUL MOUTHFUL

NEU Professor Publishes Groundbreaking Linguistics Study

A new study published by Northeastern University psychology professor Iris Berent and her colleagues supports the previous assumption that language and motor systems are intricately connected; however, their research reveals a new relationship between motor and language processes. The new findings display that the motor system does not drive linguistic principles directly. Instead, motor actions are a consequence – not the cause – of pre-existing linguistic and grammatical rules.

According to the researchers, all spoken languages express words using sound patterns, but certain patterns are preferable to others. This preference for particular sound patterns is known as the syllable hierarchy. Berent provides the example of the sound pattern "blog" versus "lbog." The "blog" speech pattern is clearly preferable, as it is readily recognized and easier to process in English speaking patterns, while "lbog" is an "ill-formed syllable," according to the research team. "Blog" is preferable as it complies with linguistic rules, not because it is necessarily easier to pronounce. The researchers' goal was to determine the exact principles behind these linguistic preferences: specifically, whether these differences reflect abstract rules banning unfamiliar and ill-formed syllables, or if the preferences relate to the motor demands associated with speech production.

To address this question, the team used transcranial magnetic stimulation (TMS), a procedure that uses magnetic fields to temporarily impair nerve cells in motor brain areas. While TMS can deliver electrical current to nerve cells in any region of the brain, the researchers particularly targeted motor areas to examine the effects of brief impairment on the lip motor region. This device tested the sensitivity of nine native English speakers with normal hearing to the natural syllable hierarchy (example: blif>bnif>bdf>lbif). In the experiment, participants were presented with an auditory stimulus – either monosyllabic or

disyllabic – and were asked to indicate the number of syllables included in the stimulus. 200 milliseconds prior to administering the sound stimulus, TMS pulses were delivered to briefly disrupt the lip motor region. The goal was to determine whether momentarily disturbing the motor regions would eliminate the linguistic preference for "blif." Therefore, this temporary disruption of the lip motor region should lessen prior dislike for syllables like "lbif," making it more susceptible to TMS. To ensure the region stimulated by TMS was representative of the syllables presented, the activation was confirmed using fMRI experiments of the same procedure.



The results of the study revealed that the repetitive TMS pulses did indeed impair participants' ability to accurately determine the number of syllables in an auditory syllabus, and fMRI data confirmed that the cortical areas stimulated were sensitive to the syllable hierarchy. These findings agree with previous studies that speech production automatically triggers motor action. However, the results conflicted with the hypothesis that ill-formed syllables exert the greatest motor demand. Instead, the researchers found that "lbif" syllables are least likely to be disrupted by TMS. Additionally, a follow-up MRI revealed that these ill-formed syllables are least likely to engage the lip motor area in the brain. This demonstrates that "lbif" syllables are not disliked because of their motor demands, but

motor demands reflect linguistic preference, as linguistic preferences persist even when the language motor systems are disrupted.

Furthermore, the researchers suggest that these results could have future implications in studying language-based learning disorders linked to the motor system, such as dyslexia. According to Berent, who specifically researches dyslexia, "This has huge theoretical implications. The idea that linguistic knowledge is fully embodied in motor action is a hot topic in neuroscience right now. Our study shows that motor action is still very important in language processing, but we show a new twist on the mind-body connection."

The team acknowledged that their results are somewhat limited due to the study's concentration on the lip as the single articulator, and the TMS method does not entirely block motor stimulation. Nonetheless, the best explanation of the relationship between the language and motor systems still supports the idea that the motor system is engaged by well-formed, easily articulated, commonly recognized syllables within the English language. The processing of ill-formed syllables thus originates from other sources; perhaps there exists a language-wide system for encoding abstract linguistic restrictions. The team concluded their research by stating that the language and motor processes are intricately related, yet remain distinctive. As stated by the researchers, "Language is designed to optimize motor action, but its knowledge consists of principles that are disembodied and potentially abstract." ■

PNAS (2015). DOI: 10.1073/pnas.1416851112.

Engineering the Next Human Generation

BY MARK TAWFIK, BIOCHEMISTRY, 2018

It is widely accepted in the scientific community that human life is the product of gradual evolution over millions of years. However, new gene-editing technology has given humans the power to precisely alter DNA, the genetic material that codes for every cell in our bodies. As the technology develops, scientists are exploring its potential to eliminate genetic disease and improve the genes of future generations. Yet many are asking, although we can make these changes, should we?

The technology behind the controversy is CRISPR-cas9, a gene-editing tool that employs a particular protein, cas9, derived from a part of the bacterial immune system known as CRISPR. Cas9 is a special protein that can cut strands of DNA in specified regions. By taking advantage of this capability, the CRISPR-cas9 technology can be used to edit genes through the addition or deletion of bits of genetic material in specified regions.

The applications of such a tool are tremendous. One review of in the MIT Technology Review suggests that this technology could be used to correct faulty genes in patients with disorders such as sickle cell anemia. The ability to completely cure a patient of genetic disease would provide relief for countless sufferers. But some scientists hope to take things one step further by editing DNA in sperm and egg cells, known as the "germline", before they give rise to an individual. A pair of researchers at Harvard University, George Church and Luhua Yang, are rumored to be working to edit the egg cells of a woman suffering ovarian cancer from a genetic defect so as to create a viable egg cell free of the carcinogenic gene. Similar work is occurring at other universities and companies such as Boston-based OvaScience to develop methods of eliminating genetic illnesses from future generations through germline modification.

Editing the germline is intensely controversial, as any changes made would pass on to future generations. Germline engineering is banned in 12 countries, but not the United States. The fear is that gene-modification will move beyond simply eliminating genetic diseases and into the realm of designer-babies; a new generation of humans whose appearance, intelligence and physical capabilities have been culled from the best genes in the pool. There are many who say that it would be a disservice to future generations not to improve the gene pool. However, most scientists and the public are wary. The co-developer of CRISPR-cas9, Jennifer Doudna, and other scientists recently came out in a March 2015 paper calling for greater dialogue regarding the future of germline modification and made the recommendation to strongly discourage any attempts at modifying human germline cells for clinical application prior to there being a discussion among scientific and governmental organizations regarding the implications of such research. It stands to be seen how those working on germline modification will respond.

CRISPR-cas9 is a powerful tool that will undoubtedly revolutionize modern medicine by allowing for the modification of human DNA. Its use to modify the germline remains a controversial issue and it will be interesting to see over the next few years how world opinion develops and the extent to which gene-editing will be employed. ■

Cell (2014). DOI: 10.1016/j.cell.2014.05.010.



CATCHIN' SOME WAVES

BY JAMESON O'REILLY, APPLIED PHYSICS AND ELECTRICAL ENGINEERING, 2019

Early last year, the scientific community was set ablaze by an announcement from BICEP2, a group of scientists working near the South Pole. They claimed to have uncovered evidence for the existence of gravitational waves, one of the last major predictions made by Einstein's Theory of General Relativity. The special kind of waves that the collaboration claimed to have detected had the potential to provide a treasure trove of information about the still poorly-understood origins of our universe.

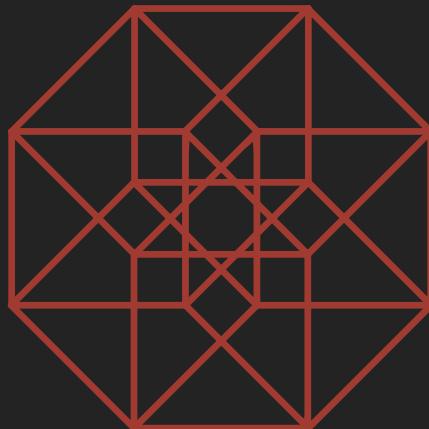
Unfortunately, on January 30 of this year, the European Space Agency officially recanted the findings. The patterns of polarized light that were originally identified as coming from primordial gravitational waves are also characteristic of the patterns created when the light travels through dust in space. The places in the sky with the most interference from dust also had the strongest gravitational wave signals, meaning that most of the signal was coming from the dust.

Although this is disappointing, it does provide a good example of the scientific method at work and has renewed both public and research interest in gravitational waves. To understand why this is, we must first discuss what exactly gravitational waves are. We are all familiar with Newton's view of gravity, that all mass is attracted to other mass through the gravitational force between them. The strength of this force is dependent on how much mass each object has as well as how far apart they are. Because the force causes the bodies to move, the distance between them changes, which causes the gravitational force between them to change.

According to Newton's understanding, this information is transferred instantaneously between the bodies so that there is no delay in the updates to the gravitational field taking effect. However, Einstein recognized that this could not possibly be the case because nothing in the universe has been found to travel faster than the speed of light, including the information about the force being transferred between the two bodies.

According to General Relativity, the information about the gravitational forces is carried by gravitational waves moving at the speed of light. Like sound waves

which travel through air, these gravitational waves travel through space-time, a four-dimensional space made up of the three spatial dimensions in addition to time. When sound waves travel, some air carrying the sound squishes together while other parts of it get pulled apart. A very similar process is happening with gravitational waves, but in that case it is space-time itself that is getting stretched. These distortions have far-reaching conceptual implications.



Perhaps the most important of these implications involves a process called the Inflationary Hypothesis. The Inflationary Hypothesis is the idea that within a tiny fraction of a second after the Big Bang, the universe expanded very, very quickly. This hypothesis accounts for a number of things that the Big Bang alone cannot, including the uniformity of the distribution of matter across space. It is also the only thing that could have amplified the gravitational waves enough to make them detectable today. The waves are usually tiny, much smaller than a single atom, because the gravitational force is much weaker than the other fundamental forces. This makes them very difficult to detect, but if the Inflationary Hypothesis is correct, this expansion would have released huge amounts of gravitational waves that would still travelling throughout the universe. Confirming the Inflationary Hypothesis would bring us much closer to understanding how our current universe came to be. These gravitational waves, the ones left over from the very beginning, are what BICEP2 thought they had detected.

The BICEP collaborations, now updated to BICEP3, studied patterns in microwave background radiation from space for evidence for waves, but this is not the only way that scientists can detect gravitational waves. Currently, scientists are collaborating with the Laser Interferometer Gravitational Wave Observatory, or LIGO, to detect gravitational waves. The LIGO, based jointly in Louisiana and Washington State, attempts to detect waves using two interferometers, or wave detectors: one in each state. An interferometer is a set of two perpendicular arms about four kilometers long. A laser is split at the junction between these two arms and the two beams travel down their respective arms. At the ends, they are reflected and travel back down to the junction. The arms are calibrated very carefully to make sure that they are as close to the same length as possible, so any disturbance in this balance can be detected by keeping track of the interference between the two returning beams. The interference is how the wave patterns add together.

This process takes advantage of the fact that when gravitational waves move through an area, they stretch the space one way and squish it in the direction perpendicular to the stretching. This stretching will hopefully alter the lengths of the two arms of the interferometer so that they are measurably different. If there is a difference in the lengths of the arms, it will take different amounts of time for the lasers in each to travel up and down their respective arm, so they will return to the junction at different times. This shift can be measured by examining the interference pattern from the light beams because different shifts each result in distinctive patterns.

With both LIGO and BICEP3 preparing for their most sensitive runs yet, it would appear that the world is once again on the verge of a major breakthrough, one that some consider more significant than the discovery of the Higgs Boson. A confirmed detection of gravitational waves has the potential to fundamentally alter our understanding of the universe, which will undoubtedly lead to further investigation. For now, all we can do is wait. ■

SOCIAL BUTTERFLY vs. GO-GETTER

TWO TYPES OF EXTROVERTS

BY CHRISTINE GEORGIOU, ENGLISH, 2017

Most people associate extroverts with the life of the party and picture introverts at home enjoying the company of a good book. In reality, the differentiating factor between introversion and extroversion -- personality traits first popularized by the influential behavioral psychologist Carl Jung -- lies in how individuals gain energy. Introverts lose energy from social interaction and need time alone to recharge. Conversely, extroverts gain energy from others.

A 2005 study led by Michael Cohen, now of the University of Amsterdam, shows that these individual personality differences can be linked to brain activity and dopamine regulation. When involved in risk-taking behavior that paid off, such as gambling, extroverts exhibited a stronger response in two key brain regions: the amygdala and the nucleus accumbens. The amygdala is the part of the brain responsible for processing emotional stimuli, and the nucleus accumbens, a key part of the brain's reward circuitry and dopamine system.

Extroverts also showed a higher release of dopamine, the "pleasure hormone," in response to a positive outcome from risk-taking behavior, than did the more introverted groups. But what factors motivate extroverts to engage in the luck of the draw and seek out frequent interaction with others?

Recent studies show that extroverts can be further divided into two groups: 'agentic' go-getters, and 'affiliative' people-people. While affiliative extroverts find sharing affection and affiliation with other reward enough, agentic extroverts are goal-oriented and further motivated by a desire to claim the spotlight.

A recent study published in *Cognitive, Affective, & Behavioral Neuroscience* shows the first evidence linking each type of extroversion to differences in brain anatomy.

A research team led by Erica Grodin and Tara White of Brown University first administered mental and physical health screenings to volunteers. 83 healthy participants then took standard personality tests measuring the two differing types of extroversion and underwent MRI scans designed to detect the amount of grey matter in specific brain regions.

As predicted, researchers found that both types of extroversion were correlated with higher volumes of grey matter in the left and right medial orbitofrontal cortex, both involved in the decision-making process. However, subjects with higher degrees of agentic extroversion also had more grey matter in the left parahippocampal gyrus, left cingulate gyrus, left caudate and left precentral gyrus in both men and women, and the right nucleus accumbens in men.

The right nucleus accumbens is involved in the recognition and volitional motor approach of reward -- the part of the brain that identifies rewards and actively decides to pursue them. The other brain regions mentioned are involved in cognitive control of behavior and the planning and execution of voluntary movement.

"So it actually makes sense that this dimension of temperament and personality that's sort of a get-yourself-out-there-in-the-world thing is related to gray matter volume in those regions," said Tara White, assistant professor (research) of behavioral and social sciences in the

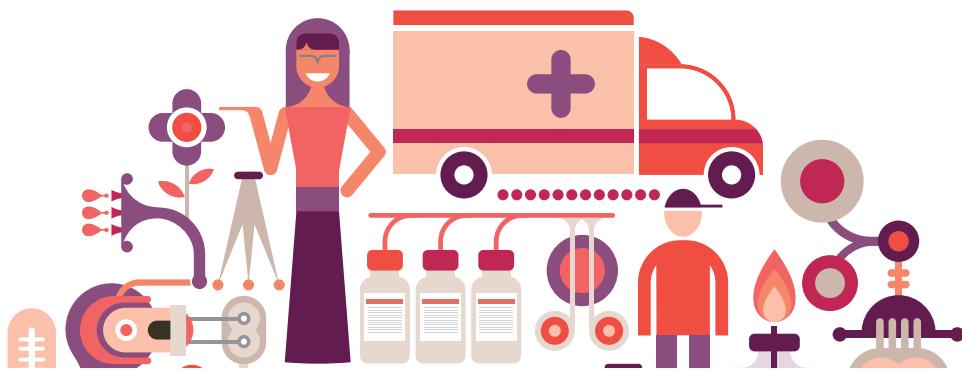
Brown University School of Public Health, and corresponding author of the new study, in a *New York Magazine* article.

The results of this study also create a strong case for the importance of self-reporting in psychology. While self-reports are often thought to be of minimal importance with respect to data collection, in this instance, the results of the personality tests were supported by the MRI scans. The link between the individual's world view and the volume of grey matter in their brains shows that self-reporting is, often, an accurate and reputable source of psychological data.

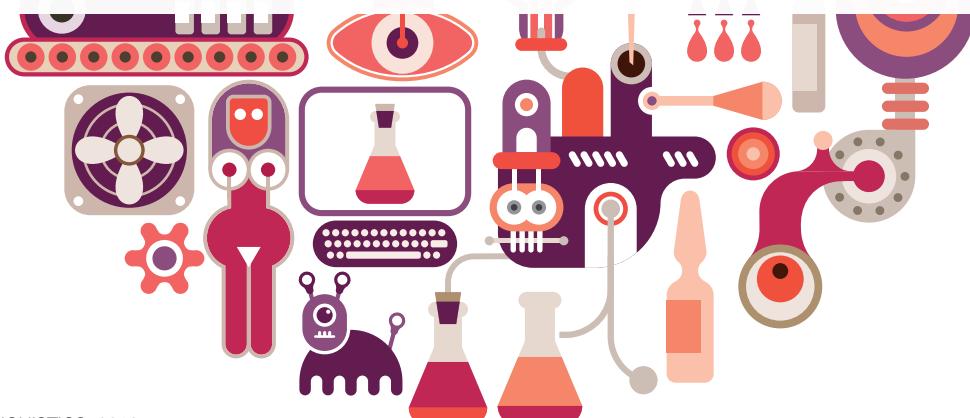
"These are people just sharing with you how they tend to experience the world and what's important to them," said White in a Brown University news article. "The fact that that's validated in the brain is really exciting. There's a deep reality there."

This study does not yet explain when the larger amounts of grey matter develop, or why they result in personality types. Grodin and White hope that the results will serve as a "developmental benchmark" from which to better understand the cause of neurological problems that can occur from aging and neurodegenerative disease in agentic and affiliative extroverts. ■

Cognitive Brain Research (2005). DOI: 10.1016/j.cogbrainres.2005.09.018.



SCIENTISTA



BY ADANYA LUSTIG, LINGUISTICS, 2018

Scientista, a new club at Northeastern, is a chapter of a national organization whose goal is to empower women in science. Leah Simmons, president of Scientista at Northeastern, feels passionately about how important it is to bring women together in order to work towards solving the problem of the lack of women pursuing Science, Technology, Engineering and Math (STEM) careers.

"I wanted to form some sort of community where women could come into a safe, comfortable space and be able to seek out like-minded peers that could connect them in a lot of other ways and create one big network of women," said Simmons.

Megan Fowley, chair of department affairs, feels like this type of community is missing from science classes because of the nature of the material and the lack of group work.

"At [Scientista's] first brunch I talked to a girl who's been in at least five of

my classes and that was the first time I'd ever talked to her," said Fowley.

This community of women is especially important because, according to the National Science Foundation, the undergraduate years are when many female students move away from science and technology fields. Michelle Castor, the club's treasurer, remarked that she hasn't seen many initiatives to help bring women into science at Northeastern.

**"IT IS AN INCLUSIVE
ORGANIZATION, WELCOMING
ANYONE WHO WANTS TO SUPPORT
WOMEN PURSUING SCIENCE."**

"Personally, I haven't noticed any effort on [Northeastern's] part, but I haven't really sought it out," said Castor. "I think if you want to be a woman in science you have to have that ambition and seek it out."

The club only began this January, so they are just getting started and figuring out how best to serve the community of women in STEM at Northeastern.

"The national organization is really great at giving a skeleton of how the year should go, but they also keep it pretty free-form—every chapter kind of does its own thing," said Simmons.

They may be still getting on their feet, but it's clear that the Scientista e-board cares about providing an on-campus resource for women in STEM. For example, they presented at an event in March to inspire young girls' interest in science, hosted by Northeastern's Science Club for Girls. The club isn't limited to women: they are an inclusive organization and they welcome anyone who wants to support women pursuing science.

"I really wanted to start Scientista because I've always been about women's empowerment and I think that especially in science, our voices are underrepresented," said Simmons. ■

HIGH TECH TALK: THE NEWEST WAVE IN MEDICAL INNOVATION

BY ALESSANDRA MAAHS, BIOLOGY AND ENGLISH, 2017

To succeed you must fail, often." We have all heard this phrase many times when given advice on how to succeed. At the High-Tech Med Talk, which took place on March 10 and is part of Harvard's 'Mini-Med School Series,' doctors Elazer Edelman, Conor Evans and Jeff Karp have all proved that one must fail in order to succeed. The moderator of the evening, Elazer Edelman, MD, Ph.D., Director of Harvard-MIT Biomedical Engineering Center and Cardiologist at Brigham and Women's Hospital, began by explaining that innovation in the world of medicine is not a straight and fast road, despite how good the final product may look. The barriers researchers and physicians encounter every day are huge. For instance, the amount of funding the government allocates to innovation every year is negligible. Through extensive research and innovation, Dr. Edelman's team has developed a stent-based drug delivery system which has helped decrease cardiovascular disease sixfold over the past 40 years. Dr. Edelman believes that we are living in one of the most innovative periods in history and wants to further educate the public about innovations occurring all over the world.

Dr. Conor Evans, a researcher at the Wellman Center of Photomedicine and Assistant Professor at Harvard Medical School, has been trying to solve problems with photomedicine (light interacting with tissues) since he joined Wellman in 2010. Photomedicine involves the study and application of light to develop innovative medical products or new approaches to providing patient care. Two of the projects that Dr. Evans has been working on are SMART Bandages and Virtual Biopsies. Virtual Biopsy involves using scattering light called Optical Coherence Tomography, which advances clinicians' ability to assess and manage disease. This biopsy is non-invasive and creates a 3D image with a light beam. The concept of creating a 3D image has been explored further

through a pill containing OPT technology that a patient can swallow, which scans the entire esophagus to diagnose Barrett's esophagus, a gastrointestinal reflux disease that has a strong association with cancer. Lastly, Evans explained that his new SMART bandages could map oxygen concentrations in skin burns and other wounds. This liquid bandage glows green when the tissue is oxygenated and red when there is less oxygen. He hopes to make the SMART bandage technology compatible with smart phones in the near future.

"WE ARE LIVING IN ONE OF THE MOST INNOVATIVE PERIODS IN HISTORY."

"As we encounter challenges we approach them the same way and expect a different outcome. We have been educated out of being creative and we must break free from this repetitive process," explained Dr. Jeff Karp, Associate Professor at Brigham and Women's Hospital, Harvard Medical School. Karp is trying to establish a paradigm shift to improve the quality of patient's lives. In one of his projects, he is trying to find solutions for young children with heart conditions who need on-demand adhesion. During a trial, his team created a patch using viscous and hydrophobic glue—inspired by the secretion of insects—that repels water. This patch did not end up working because it was too small; however, his team scrapped up some remaining glue to seal the wound and it functioned

perfectly. This is a great example of how initial failure can ultimately lead to success.

Dr. Karp and his team have developed a company called GECKO Biomedical, which is pursuing this technology to simplify surgical procedures, specifically minimally invasive surgery. "This has the potential to replace staples," announced Karp.

Both Evans and Karp did not receive any funding for their first, second, or even third grants. Both have written hundreds of grants unsuccessfully, which has only motivated them further. Through persistence, they have been able to turn those failures into successes, creating the perfect recipe for accomplishment.

This new and exciting wave of medical innovation has potential to significantly change and advance daily medical practices. The only question is: how soon will innovation be adopted by clinicians globally? ■

This article was first published in relation with the BWH Brigham Research Institute.



NOT A SMOOTH MOVE

BY HANNAH WEISMAN, BEHAVIORAL NEUROSCIENCE, 2018

Some of our favorite ice cream brands – Turkey Hill, Dreyer's, Blue Bunny – contain certain emulsifiers that are possibly contributing to the societal trends of obesity and metabolic disease. In a recent study published by *Nature*, scientists have found increases in metabolic syndrome and intestinal inflammation in mice, which were fed relatively low concentrations of two commonly used emulsifiers found in packaged foods. This research is significant as it suggests the use of emulsifying agents to create a smooth consistency in packaged foods, which can produce similarly undesirable health effects in humans.

In the study, researchers fed two emulsifiers, carboxymethylcellulose(CMC) and polysorbate-80, to wild-type mice and genetically susceptible mice – those that contained genes putting them at increased risk of inflammatory bowel disease or metabolic syndrome – for twelve weeks. Among the genetically susceptible mice, consuming emulsifiers increased the risks of developing the mouse-equivalent of inflammation, colitis, from 40 percent to 80 percent. The wild-type mice did not display colitis; however, they showed mild intestinal inflammation and features of metabolic syndrome including weight gain, high blood sugar levels, and increased body fat. The mechanism by which emulsifiers produce these changes remains uncertain. However, it appears that emulsifiers may directly damage the mucus lining separating the intestinal lining from bacteria. The mucus lining allows the majority of gut bacteria to be separated from the epithelial cells lining the intestines. Therefore, disturbances to this mucus surface leave the intestines more prone to bacteria and subsequent inflammation. The emulsifiers may also indirectly change the microbiome – the microorganisms of our body – by favoring mucus-invading microbes within the intestinal environment, thus increasing the likelihood of developing inflammation.

Despite the believable results of the study, the researchers caution in drawing a cause-and-effect relationship between emulsifier use and inflammatory disease. Other artificial changes and unnatural additives to our food may also be disrupting the body's immune system, increasing vulnerability to chronic inflammation; therefore, it is difficult to pinpoint one factor as the most damaging component. The researchers even assert that the current methods of testing of food additives to detect toxicity may be inadequate, and additional studies are necessary to determine the full effects of preservatives on health. To further research emulsifier effects, the same group will be embarking on a new long-term study comparing the intestinal health of people who avoid emulsifiers completely with those who maintain a regular diet. ■



DEEP-SEA HYDROTHERMAL VENTS: A NEW FRONTIER FOR DRUG DISCOVERY

BY GWEN SCHANKER, JOURNALISM AND BIOLOGY, 2018

The growing problem of antibiotic resistance is getting out of hand. More and more antibiotics are gradually losing their ability to kill bacterial growth, making them ineffective against pathogens of disease. The situation is causing scientists to seek solutions from a number of outlets. Turning the issue around will require an out-of-the-box solution – maybe even from the depths of the ocean.

**“THE GROWING PROBLEM OF
ANTIBIOTIC RESISTANCE IS
GETTING OUT OF HAND.”**

“Natural product” research, the process of unearthing chemicals in nature that can be used in drug discovery and design, has played a key role in biological and chemical research in recent years. Many new antibiotics have originated from naturally occurring compounds. One key example of natural product research that has been particularly relevant for marine scientists is the potential for deep-sea drug discovery, namely through hydrothermal vents.

The depths of the ocean are so vast that many have yet to be explored, representing something of an untapped frontier. Hydrothermal vents, crevices in the earth’s surface out of which geothermal heat flows, were first discovered 200 miles off the coast of the Galapagos in a 1977 expedition. In what’s been described as one of the greatest biological discoveries of all time, scientists aboard Alvin, a deep-sea research submarine operated by the Woods Hole Oceanographic Institution, discovered the vents, which tend to form in places where there is volcanic activity and which have their own unique ecosystem. The fluid spewing out of these geysers in the ocean floor contains a number of chemical compounds that have the potential to be used in drug discovery, and what’s more, the environment is inhabited by a number of organisms that contain unique molecules, representing a completely unexplored spectrum of scientific research that may play a role in future drug discovery initiatives.

Image courtesy of Public Library of Science



These organisms, mainly tubeworms and other invertebrates, survive through a process known as chemosynthesis. The process of chemosynthesis is similar to photosynthesis: carbohydrates are created using carbon dioxide and water, but sunlight does not play a role. Instead, the organisms are fueled through reactions that use inorganic chemical nutrients, such as sulfates and ammonia.

The initial discovery of these vents catalyzed an entirely new phase of marine drug discovery research. Richard Lutz, who is considered one of the world's prime experts on deep-sea hydrothermal vents, was on one of Alvin's earliest deep-sea expeditions in 1979, and has been on numerous dives since. Lutz has served as principal investigator on a number of research projects regarding hydrothermal vents and has collaborated on more than 100 studies published in *Nature* and various other scientific journals that describe molecules with potential anti-disease properties.

According to Lutz, the initial goal of deep-sea vent research was to amass a large collection of samples of organisms from vents all around the world. This task took approximately 10 years to complete. The next step was to take extracts from each organism – mussels, tapeworms, and otherwise – and isolate the compounds present. The researchers then attempted to find a match with an anti-disease agent, to determine if that compound could be used to develop a drug to fight that disease.

"The reason the vents are so interesting is that they are the most extreme environment on the planet," Lutz said. "These organisms have been isolated from the rest of the world and are in environments that are highly carcinogenic. The question is, are there compounds associated with them that are able to serve as anticancer agents?"

Recently, Lutz and his colleagues began to investigate the potential for the development of drugs from compounds found in deep-sea vents in earnest. Since the early 1990s, they have collaborated with the National Cancer Institute (NCI) in a project in which they

match their found organisms with maintained cancer cell lines within the NCI database.

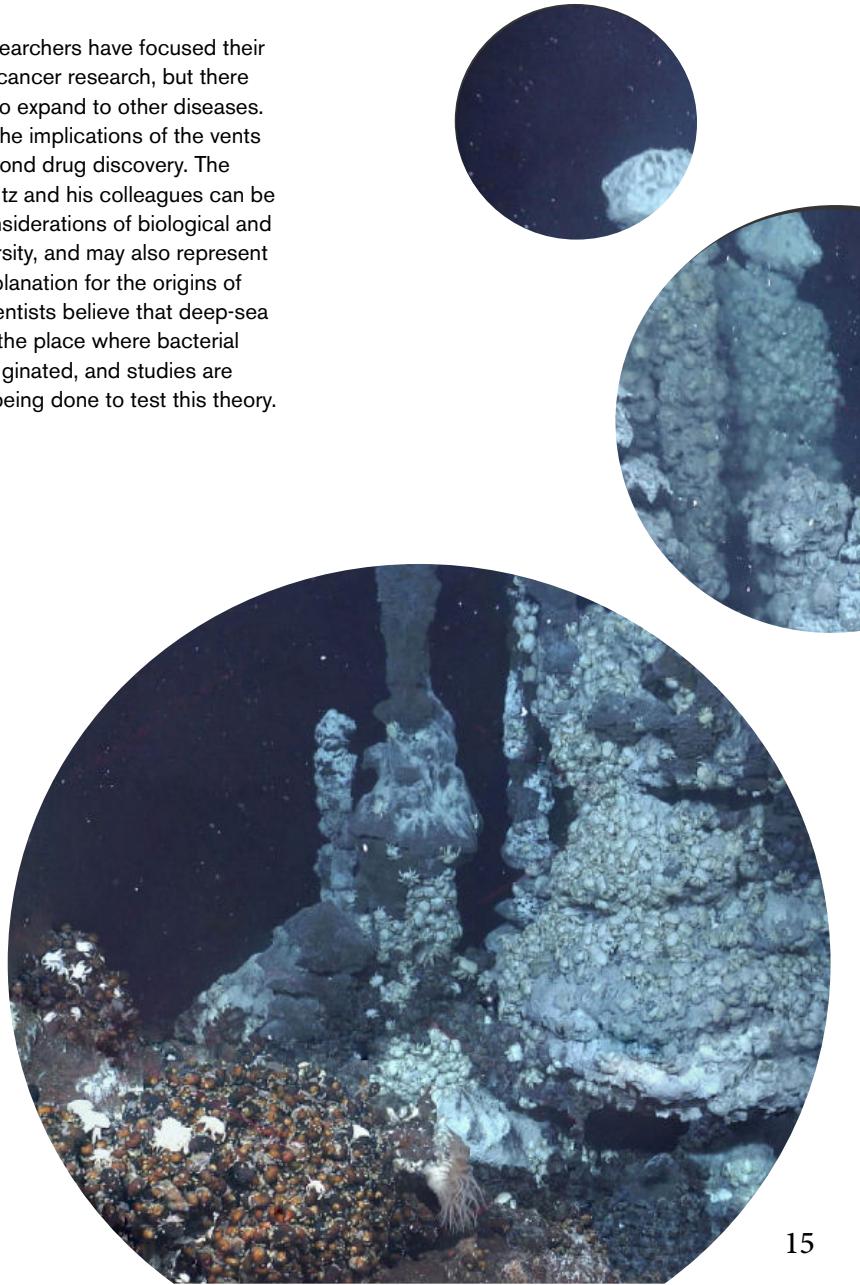
Lutz calls the findings the researchers have amassed so far – that is, the matches between extractions from deep-sea organisms and the 60 existing NCI cell lines – "remarkable." "By taking these vent organisms, we've found a high number of fits," he said. These matches indicate the potential for the design of new drugs that could combat cancer. Furthermore, the sheer amount of molecules discovered thus far may provide a solution to the issue of antibiotic resistance.

"There's a whole spectrum of exciting discoveries with the vents – it's not just drug discovery," Lutz said.

Lutz and other deep-sea researchers are interested in forging relationships with pharmaceutical companies who can help to bring their initial research to fruition. The potential implications of future research on the ecosystems of deep-sea hydrothermal vents is huge, and future discoveries by Lutz and his colleagues may improve the issue of drug resistance that is such a concern today. ■

"THE SHEER AMOUNT OF MOLECULES DISCOVERED THUS FAR MAY PROVIDE A SOLUTION TO THE ISSUE OF ANTIBIOTIC RESISTANCE."

So far, the researchers have focused their efforts on anticancer research, but there is a potential to expand to other diseases. Furthermore, the implications of the vents extend far beyond drug discovery. The research of Lutz and his colleagues can be applied to considerations of biological and chemical diversity, and may also represent a potential explanation for the origins of life. Some scientists believe that deep-sea vents may be the place where bacterial activity first originated, and studies are continuously being done to test this theory.





STRANGER THAN WE KNEW: FOREIGN GENES MUCH MORE PREVALENT THAN THOUGHT

BY ASA BUDNICK, BIOLOGY , 2019

A new study has shown that genes from Horizontal Gene Transfer (HGT) are much more common in animals than was previously thought. The study investigated genomes from numerous species of flies, nematode worms, and primates—including humans—and in each case found a significant number of genes that likely originated from a foreign organism. HGT is a relatively well-known phenomenon amongst single-celled organisms, which frequently exchange genetic material, but this is the first study to demonstrate a large incidence of HGT between animal and non-animal organisms throughout evolutionary history. The high incidence of HGT in these animals may significantly alter our model of how genomes are shaped over time.

HGT is one of the rare instances of a complicated biological process that can be explained easily and exactly through an analogy to an old advertisement for candy:

A man and a woman are walking opposite ways down a street--one eating peanut butter, and the other eating a chocolate bar. They collide, and a new chocolate peanut butter treat is born.

Of course in HGT the man and the women are single-celled organisms and instead of walking they are just wiggling around, and instead of swapping edibles to create a tasty new candy they exchange bits of DNA that later get absorbed into the host genome. HGT is recognized as an important mechanism of genetic variation in single-celled organisms and it is estimated that on average 81 percent of prokaryotic genes have been involved in HGT.

Prior to the publication of this most recent study, HGT between a single-celled organism and an animal had not been conclusively shown. Prior studies had found evidence of some genes that likely resulted from HGT in flies, nematodes, and humans, but they had neither the sample size large enough, nor genome records adequate to confirm HGT had occurred. The new study tested a large group of genomes: 12 *Drosophila* species, 4 *Caenorhabditis* species, and 10 primate species. This study also had access to a much larger and less contaminated database of potential HGT donor species including fungi. The study was able to confirm several of the selected genes from the original study and found an astonishingly high number of new genes from HGT. Of studied species nematodes presented an average of 173 genes, primates an average of 109, and flies an average of 40 genes from HGT per species.

The study identified genes that were likely transferred from a single-celled organism by running comparative genomics on each individual species in reference to both the taxonomic group and a host of potential HGT donors. The genes found similar to those in single-celled organisms, and which had no match in other members of the same taxa were declared to have likely come from HGT.

A functional analysis of HGT genes was also run with interesting results. According to the study, a fat mass and obesity associated gene, found only in vertebrates and in algae, arose in humans, likely as a result of HGT. The gene for ABO blood types was also shown to be a result of HGT. A general analysis of HGT genes found that the vast majority were operational genes, and of

these a shockingly high amount coded for metabolic enzymes. Another interesting discovery of the study was that genes from HGT possessed introns – segments of code that must be spliced out of RNA before translation – which was unexpected because single-celled organisms contain neither introns nor the capacity to splice them out prior to translation. This suggests that genes gained through HGT are given introns overtime in the host cell DNA, and that there is a specific mechanism that allows for the generation of introns.

Ultimately this study shows that the genetic histories of the earth's organisms are more complicated than we thought, and that HGT may play a very significant role in the development of all organisms on earth. It also highlights the fact that most genes from HGT are functional and play important metabolic roles, which are adapted through the addition of introns. This indicates that animals have adapted to maximize the utility of HGTs. The study shows that, far from being a small component of single-cellular genetic variation, HGT is a significant phenomenon fully integrated into the infinite beauty and complexity of life on Earth. ■

Genome Biology (2015). DOI: 10.1186/s13059-015-0607-3.

MEGADROUGHTS:

THE DRY AND DUSTY FUTURE

BY CAYMAN SOMERVILLE, ENVIRONMENTAL SCIENCE , 2017

The United States is known for its diversity in people, vegetation and climates. Unique regional climates create the niche conditions for certain species' habitats. For example, the greater roadrunner (*G. californianus*) is exclusive to southwestern US, where it lays its eggs among bushes or cacti and preys upon desert insects, spiders and serpents. Its habitat is just one example of climates under threat from the increasing prevalence of "megadroughts."

In 2010, National Aeronautics and Space Administration (NASA) issued a consensus among 18 American scientific associations: 97 percent of climate scientists agree that "climate-warming trends over the past century are very likely due to human activities." The regional impacts of global warming are expected to be disproportionate, varying from one geographic location to another, depending on their particular temperatures and precipitation levels. Megadroughts, droughts that last for more than three decades, will occur in only certain regions.

This past February, NASA published a study depicting the disturbing future for the U.S. Southwest and Central Plains. Using climate models that incorporate soil moisture data to estimate the 21st century drought risk, NASA scientists determined that these regions should expect drier and longer droughts than any conditions seen in the last 1,000 years. The new analysis builds on

several recent studies that forecast these regions to experience "extensive droughts in the second half of this century." However, NASA's report found that drought conditions in both regions would be even more severe than all previous predictions—worse than the megadroughts of the 12th and 13th centuries, which were once considered the "hottest, most arid extended droughts."

likelihood of a megadrought persisting in the Southwest and Central Plains is 12 percent. If greenhouse gas emissions are mitigated by 2050, the researchers claim a megadrought is 60 percent likely. Alternatively, if emissions continue along their current trajectory of increase, the likelihood of a decades-long megadrought in these regions reaches 80 percent.

"THE ADVANCING OF 'HUMAN-PRODUCED' GREENHOUSE GAS EMISSIONS ACCELERATES THE RISK OF SEVERE DROUGHTS"

The researchers found that the advancing of "human-produced" greenhouse gas emissions accelerates the risk of severe droughts in these two regions. The study, published in *Science Advances*, is based on tree rings, which shed light on past droughts and climate models and can predict future droughts. Soil moisture data taken 30 cm below the top layer was standardized to the Palmer Drought Severity Index and deviated from the 20th century average. Using this index, climate scientists analyzed the soil moisture data sets from 17 climate models.

These were used to create two emission scenarios through the year 2100: a diminished emissions scenario or a high emission scenario. Currently, the

Ben Cook, the lead author of NASA's study, stated: "What these results are saying is we're going to get a drought similar to [past megadroughts], but it is probably going to last at least 30 to 35 years." Similarly, the United Nations Intergovernmental Panel on Climate Change (IPCC) released a Fifth Assessment Report, which reported that there was low expectation that soil moisture, one of the main indexes of drought, would increase.

As scientific understanding of rise in Earth's average temperature is advanced, an increased urgency to mitigate greenhouses gases becomes palpable. ■

Science Advances (2015). DOI: 10.1126/sciadv.1400082.



DISTRACTION

FUELING YOUR INNER GENIUS?

BY NATASHA MATHUR, BEHAVIORAL NEUROSCIENCE, 2018

It is hard to imagine exactly what differentiates people between good and great, but based on what is known about quite a few great minds there is one common occurrence. Marcel Proust, Charles Darwin and Richard Wagner were all plagued by the inability to tune out distracting noise. In spite of this, the three men were all extremely creative and innovative in their ways of thinking, and they were all able to excel in their fields. But what made them achieve so much more than all their competitors? What caused them to become the envy of so many? There have been and will no doubt continue to be studies on this, but very recently scientists at Northwestern think that they have uncovered something important.

The human body encounters thousands of different stimuli everyday – the feel of carpet on the bottom of your feet, the wailing of an ambulance rushing past, just to name a few. In addition to recognizing these novel stimuli, the human body, more specifically the brain, is also able to filter them out. When the body does this, we no longer focus on what our feet feel, we forget the ambulance in the background, and focus on whatever needs our immediate attention—while everything else becomes background noise. In order to be most productive, most people prefer to filter out things that are not relevant to what they are working or focusing their attention on. However, there are people who actually get their inspiration from these external stimuli. In a recent study done by Northwestern University and published in *Neuropsychologia*, researchers hypothesized that the inability to completely filter out external stimuli may be related to creativity.

Many great minds, for example Marcel Proust, have had trouble filtering out irrelevant noises. This may not be the hindrance that others believe it to be – this inability to focus just on the task at hand may have played a role in his literary achievements. The lead author of the paper, Darya Zabelina, stated that ““leaky” sensory gating, the propensity to filter out “irrelevant” sensory information, happens early, and involuntarily, in brain processing and may help people integrate ideas that are outside of the focus of attention, leading to creativity in the real world.” So perhaps instead of disturbing Proust, the noises outside his window could have influenced his writing in a positive way. Maybe he was able to integrate the hullabaloo he heard outside into his work to make it more realistic and relatable.

In order to understand the relationship between attention and creativity, scientists focused on “sensory gating,” which is the ability of the brain to filter sensory information based on what is important and what is not. For example, while cooking, your brain will most likely filter out any noise coming through the window so that you focus on the stove. However, not all brains work the same. Some people are unable to filter as much external stimuli, which can cause them to be easily distracted. In order to measure sensory gating, the participants were asked to listen to two sounds per trial while staring at a cross on a screen. In order to determine a marker for sensory gating, scientists compare the “extent to which the second click is inhibited compared to the first click,” in other words how much the brain tunes out the second noise because it is no longer novel.

In this study 100 participants performed a two-part experiment. The first portion of the experiment involved the participants reporting their real-world achievements in creative areas. The second portion of the experiment involved a divergent thinking test, which is used to measure “creative cognition.” The participants were given several unlikely scenarios and had to respond within a certain amount of time. Based on the number, as well as the originality of the answer, the participant was given a divergent thinking score. The results of the study revealed that those who had divergent thinking were associated with selective sensory gating—meaning that more stimuli were being filtered out. The real-world achievements were associated with a “leakier” sensory gating system, meaning that less was filtered out.

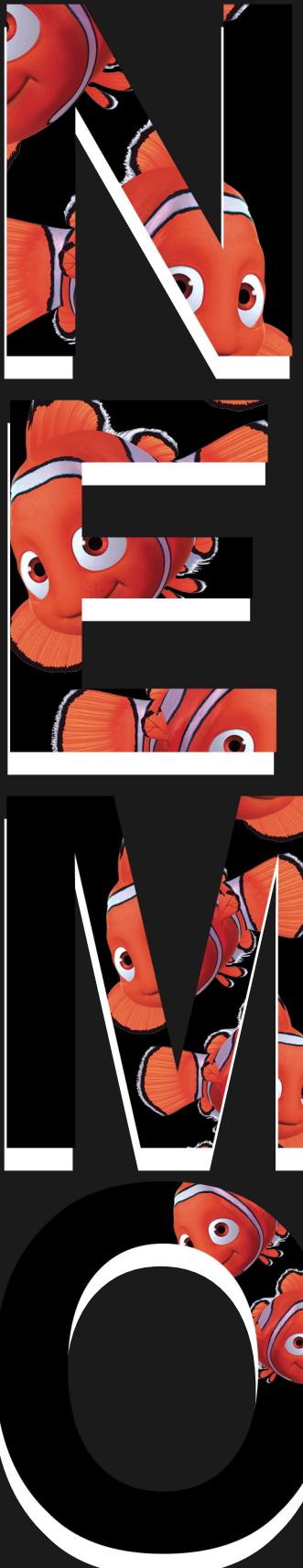
Putting this information into the context of the real world, the findings are very influential. For example, nobody will ever know to what extent Proust’s sensory gating system was leaky, but we can now begin to imagine the toll it must have taken on him. Many of us take for granted the ability to focus our attention on one thing, but perhaps for many artists the inability to focus was a downfall. There is no one thing that makes a genius; there are hundreds if not thousands of factors involved. But this study brings us one step closer to understanding how the mind of a genius may work, and how ideas and thoughts may be formed not from constant focus, but from the integration of our surroundings. ■

Neuropsychologia (2015). DOI: 10.1016/j.neuropsychologia.2015.01.034.

LOSING

The Ticking Clock on Marine Defaunation

BY RACHEL STODDARD, BIOLOGY , 2017



It is no secret to mankind that humans negatively impact many animals and species. Our history has been fraught with instances of human-caused extinctions, with some studies putting the first extinction as early as 132,000 years ago. However, the focus in these conversations has always been centered on terrestrial fauna. The vastness of the ocean and the relatively low direct contact with humans established the belief that human activity had little to no impact on the oceans. In the past few decades, however, more and more evidence has piled up showing that humans are in fact disturbing marine ecosystems.

This past January, leading marine scientists from several institutions, including University of California Santa Barbara, Rutgers University, and University of Washington, collaborated on a comprehensive review of current marine defaunation. Their research found that in the past 514 years, there have been only 15 marine animal extinctions, in comparison to the 514 terrestrial animal extinctions. While this may initially appear encouraging, their deeper analysis of marine populations and ecosystems showed cause for deep concern about the fate of the ocean.

The ocean has less endemism than terrestrial environments—meaning that it is more rare to find marine species with only one small, specific habitat. While lower rates of endemism may contribute to the lower rates of species-wide extinction in the oceans, further analysis showed that local extinction was very common in marine fauna, with up to 90 percent of pelagic fish, those that humans are most likely to come across, experiencing range contractions. Analyses also showed that ecological extinction and commercial extinction was

also on the horizon for many marine species if human activity continues in the same direction. To make matters worse, habitat loss in the ocean is steadily increasing from the overabundance of nutrients in the water—also known as eutrophication—primarily from agricultural run-off, seabed mining, port traffic and many other factors that are contracting the area of the ocean that can be safely occupied by marine life.

As of right now, marine animals are facing extinction rates comparable to terrestrial defaunation rates pre-industrial revolution, which is considered by many to be the starting point of significant human-caused environmental change. Scientists now fear that history is on the brink of repeating itself in the marine sphere. Even worse, marine habitats provide especially difficult challenges for conservationists as they are harder to access and protect. The mobility of marine animals also makes marine management a more complex task.

Despite the clear pattern of marine defaunation, the authors of the study found many reasons to be hopeful. Marine animals are still far better off than those on land, and there is still a chance to avoid the total decimation that is currently being experienced in terrestrial fauna. Conscientiousness in the next few decades in our marine management could mean the difference between marine animals thriving or facing mass extinction. ■

*The Royal Society of Publishing (2014).
DOI: 10.1098/rspb.2013.3254.*

YOUR DOG MAY SEE HIS BOWL HALF-EMPTY

BY KRISTEN DRUMMEY, BEHAVIORAL NEUROSCIENCE, 2016

If you've ever had the pleasure of being greeted at your front door by a tail-wagging canine, then you might assume that dogs are perpetually joyful balls of fur and drool. However, according to a recent study by Melissa Starling and her team at the University of Sydney, dogs may be as susceptible to bouts of pessimism as humans are.

The study looked at 20 dogs spanning several different breeds, and trained them to push a button at the sound of a tone. For one tone, the dogs received a treat in the form of a bowl of milk. For a different tone, they received a bowl of water, a decidedly less exciting result from a dog's perspective. After being trained on which tone produced milk and which one produced water, the dogs were presented with several

trials containing ambiguous tones that fell somewhere between the milk and water tones. Their judgment bias was assessed based on if and when they responded to the ambiguous tones presented to them.

The study found that there was a wide variability in how the dogs responded. Some dogs reacted more readily to ambiguous tones, suggesting that they were more likely to expect a reward and therefore could be dubbed "optimistic." Other dogs, however, were very hesitant to respond, and seemed to be afraid of the risk posed by touching the button. The researchers interpreted these dogs to be more "pessimistic," and more aversive to taking risks.

While it may seem silly to call a dog pessimistic or optimistic, the results from the

study could impact how dogs are trained and selected for jobs. For example, an "optimistic" dog that is willing and eager to take risks would be a poor candidate for a Seeing Eye dog. While the results of the study are based on a small sample size and need to be replicated, they propose an interesting new take to how we can train and relate to our canine friends. ■

PLoS One (2014). DOI: 10.1371/journal.pone.0107794.





A FIRSTHAND LOOK AT MEDICAL PROTOCOLS IN THE U.S. VERSUS ARGENTINA

BY JENNIFER OBRIGEWITCH, BIOLOGY, 2016

For my spring 2015 co-op at Northeastern, I accepted a position as a doctor's assistant in a public hospital outside of Buenos Aires, Argentina. Immediately after agreeing to the internship, I was given a slew of instructions detailing that I was not to perform any procedures above my capabilities that could potentially harm patients. I was also warned that if I were to do anything that was considered unethical in the United States while I was abroad, the American Medical Association would not allow me to matriculate in any medical school at all.

Arriving at the hospital on my first day, I couldn't help but notice differences from what I was used to while shadowing in the United States. The doctors from the oncology department meet in a café across the street from the hospital to discuss patient cases once a week; American doctors would not discuss that amount of medical information in public. In the outpatient clinic rooms, multiple patients share the same space during their appointments. The coverings on the examination beds are not changed between every patient. Doctors do not wash their hands as often as I would have expected. Patients are not asked for permission to let students observe their examinations. All of these differences shocked me during my first week, and I began to wonder where the lines were drawn in Argentine law, so I started to do some research.

According to the data privacy and personal information laws of Argentina, doctors who are treating or have treated a certain patient are able to use that patient's health information in ways that would aid in bettering the patient's mental or physical well being. Giving personal information to sources that do not promise security of information is prohibited unless it is necessary in treating a patient. Also, using medical information is allowed in surveys and research as long as the patient is unidentifiable by the published information. These three conditions are stated in the Personal Data Protection Act, but it seems that the interpretation of when it is in the patient's

interest to share his or her information is left up to the doctors. In the U.S., personal information laws are laid out much more strictly in the Health Insurance Portability and Accountability Act, with explicit guidelines for violation enforcements, public safety disclosures, and how information is to be given to spouses of both heterosexual and homosexual marriages.

"EVERY YEAR IN HOSPITALS AROUND THE COUNTRY, 23,000 PATIENTS DIE AS A DIRECT RESULT OF HOSPITAL-ACQUIRED ANTIMICROBIAL-RESISTANT INFECTIONS"

The differences in hygiene regulations are also established in the laws of each country. The CDC supplies plenty of research debating the best methods for sanitizing medical rooms and equipment, and requires frequent hand washing in order to keep the potential germs from one patient as far from other patients as possible. Argentine sanitation and sterilization protocols are much more relaxed, not requiring such separation between patients or infected areas. These differences affect the recovery of their respective patients. 11.3 percent of patients develop hospital-acquired infections in Argentina, whereas only 4.5 percent of patients acquire infections in U.S. hospitals. Because of the amount of sterilization occurring in hospitals, both countries have begun struggling with "superbugs" that have evolved into strains of bacteria that cannot be killed by the current methods of sanitation, making them stronger and more dangerous than their weaker, less sterilized counterparts might have been.

Every year in hospitals across all 50 U.S. states, 2 million patients are affected by hospital-acquired antimicrobial-resistant infections, and of this, 23,000 patients die. In Argentina, the percentage of deaths by these infections is twenty times higher. This data shows that Argentine hospitals have a higher rate of

deadly hospital-acquired infections, though less of these infections come from the powerful "superbugs" since the sanitization protocols are also lower. And if these infections are not from "superbugs," then they should be more easily treatable. Yet, the death rate is much higher.

Looking at the myriad of statistics on the subject, it seems clear that U.S. medical protocols are much more standardized, stringent, and better able to protect both the patients and doctors. So why hasn't Argentina adopted their laws? They have borrowed a few ideas, but they cannot afford to take on every protocol at once. Even working in one of the more well-financed hospitals in the country, I have seen that although doctors wish they could have only one patient to a room and use as many pairs of gloves and bed sheets as they'd like, those supplies simply do not exist. In a developing country like Argentina, the medicine is also still developing.

Patients take more time to heal or even die from wounds and diseases that they could have easily survived with the better, more available technology and medical supplies in the U.S. In this comparison between the medical practices and protocols of doctors in the United States and Argentina, the United States is proven to be more efficient, effective, and capable in every area of medicine. The next step in the scientific method dictates that we need to question why this remains so, and determine how to change the current state of affairs. Because patients in developing countries around the world deserve the medicine that would already be theirs had they happened to be born in the U.S. instead. Geography should not be anyone's cause of death. ■

DISCOVERY OF MASSIVE BLACK HOLE BAFFLES SCIENTISTS

BY LINDSAY WRIGHT, PHYSICS, 2017

Astronomers previously did not believe it possible for such a massive black hole to be created at such an early time. With a mass of 12 billion times the mass of our sun and a brightness of 429 trillion times the brightness of our sun, this object is truly remarkable. And the most perplexing part is that it was found in the early universe, only 900 million years after the Big Bang, which is very early compared to the universe's age of 13.8 billion years.

An international team from Peking University in Beijing and the University of Arizona published this groundbreaking discovery on February 26, 2015 in *Nature* magazine, breaking preconceived notions of the early universe. The black hole, named SDSS J0100+2802, is categorized as a quasar, which is one of the most energetic objects in the universe. Quasars sit at the center of massive galaxies and are fueled by supermassive black holes. These black holes eat thousands of solar masses every year, and emit the energy in two large luminous jets. As matter circles the black hole it also accelerates and heats up, adding to the brightness. The black hole, jets, and disk together is what we identify as the quasars, and they are the brightest objects in the universe.

The origin of quasars is still not fully understood, but there is a definite connection between quasars and the formation of galaxies. Scientists are unsure which forms first, the black holes at the center, or the galaxies that surround them. This new discovery strengthens the claim that the black holes in the early universe grew much faster than their host galaxies, and therefore black holes may be formed first, for that is the only explanation for a quasar so big in such a young universe. This discovery also challenges the Eddington luminosity limit, which limits the brightness that a stellar object can achieve based on its mass. This quasar is measured as being 429 trillion times the brightness of our sun, brighter than it should be at its measured mass. Could you even imagine 429 trillion suns in our sky, and how bright that would be? There are only 300 billion stars in the entire Milky Way galaxy. This quasar is bright, so bright that the light was able to travel for almost 12.9 billion years to reach our telescopes here on earth. It is amazing that we can see an object that existed so long ago.

How did astronomers see this quasar? The 2.4-meter Lijiang Telescope in Yunnan, China first discovered the quasar. Shortly after, two more telescopes in Arizona confirmed the

discovery: the 8.4-meter Large Binocular Telescope (LBT) and the 6.5-meter Multiple Mirror Telescope (MMT). But how do scientists know the brightness of this quasar when it is almost 13 billion light-years away? The light detected from the quasar is broken up into an optical spectroscopy, which is a graph of flux (amount of light picked up by the telescope) versus wavelength. The large jump in each telescope's graph is the result of redshift. Have you ever heard a siren as an emergency vehicle whizzes past your car? The sound of the siren is higher pitched as the vehicle approaches you, and lower pitched as it moves away. The same concept holds true for the wavelengths of light coming from stellar objects, what is Doppler shift for sound is redshift for light. The universe is expanding, so this quasar is moving further away from us, therefore its light is shifted. Scientists have found that the redshift for stellar objects is directly proportional to the distance of these objects from the earth, and so from the redshift you can find the distance of the object. Once we know the distance, it is easy to calculate the luminosity from the flux. The redshift calculated from this graph is 6.3, which gave scientists the distance of 12.9 billion light years away (light years is the distance traveled in one year at the speed of light, 12.9 billion light years is roughly 77 quadrillion miles, that's 77 with 24 zeros after it).

What does this mean for our current theories on the early universe? In an interview with *Astronomy*, Yuri Beletsky, an astronomer on the team that discovered the quasar remarked: "This quasar is a unique laboratory to study the way that a quasar's black hole and host galaxy co-evolve." It is commonly thought that black holes are created when stars die. These early black holes were thought to come from death of the first generation of stars, which were supermassive and lived short lives. Another theory is that unstable galaxies drove a fast accumulation of gas into a supermassive star that quickly contracted into these first black holes.

But both theories do not explain how a black hole could become as massive as the newly discovered quasar at such an early time in the universe. Dr. Max Tegmark, a cosmologist at MIT who was not involved in the discovery, said to *Huffington Post*: "The discovery of this record breaking monster black hole raises an embarrassing and unanswered question: How did it form? If it started out as a collapsing star, then its black hole ate about a billion times its birth weight to get this heavy: how did it manage to eat so much in so little time?" So this leaves us with a mystery. The current theories on black holes are no longer holding up with this new discovery. The ideas commonly accepted for how black holes and galaxies formed have been refuted. This is an exciting time for astrophysics, for the search for a new explanation has begun. ■

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Mass is a much trickier value for astronomers to estimate. Because we know the spectrum each element radiates at, light can be broken down into each element it is coming from. Astronomers have found a correlation between the magnesium II (Mg II) spectral lines and the mass of quasar; the more light we see from magnesium II, the more massive the quasar. The Gemini Telescope in Hawaii and the Magellan telescope in Chile were able to measure the Mg II spectral lines and estimate the mass of the quasar, finding it to be 12 billion times the mass of our sun.



NATURE ALWAYS FINDS A WAY



BY CICELY KREBILL, BIOCHEMISTRY, 2019

Many human pandemics including HIV and H1N1 are the product of viral host shifts, or the transmission of a virus between species. They are often caused by mutations that allow the pathogen to enter a host cell with the greatest efficiency, maximize its virulence, and increase its transmission ability so that it may thrive in different viral hosts. These viruses are the subject of constant research, not only because of their effects on humans, but also because of the wealth of information they can provide about viruses and their evolutionary ability. One such virus is the dengue virus (DENV).

“STUDYING VIRAL EVOLUTION IS VERY DIFFERENT FROM STUDYING THE EVOLUTION OF HUMANS OR OTHER SPECIES.”

Because of the multiple strain roadblock that initially slows work on vaccines, a lot of progress has been made in understanding the virus as a whole, as researchers look for other ways to prevent or halt its spread. For example, researchers know that to be able to host shift, the virus has to mutate and select the “fittest” genomes.

However studying DENV doesn't just provide information about the virus itself, it provides further information on viral evolution as a whole. “Viruses are good subjects for evolutionary studies in the laboratory or even in nature because they replicate very rapidly and can produce millions of new progeny,” Dr. Carol Blair of Colorado State University (CSU) says. Blair works in the Arthropod-

borne and Infectious Diseases Laboratory at CSU, focusing a lot of her research on the dengue virus. Studying viral evolution is very different from studying the evolution of humans or other species, simply because, as Blair puts it, “there are no fossils.” This forces scientists to study viral evolution going forward, as it's harder to look to the past to infer how the virus has evolved. Each virus evolves at a different rate and it can be hard to determine common ancestors.

Driven by her own curiosity as well as the hope that research on genetic selection will help create strategies to interrupt the transmission cycle, Blair began to research just that. Recently her research group, in tandem with researchers from the Fundación Instituto Leloir-CONICET led by Dr. Andrea Gamarnik in Buenos Aires, published a paper in which they proposed a new hypothesis for the genetic selection that occurs in DENV.

The original testing included growing the virus alternately in mammalian and mosquito cells and genetically sequencing its RNA before and after the host switch. Blair then carried out the experiment in live mosquitoes. She was both surprised and excited to find that her results mirrored those in the preliminary cultured cells, as this isn't always the case.

They found that the virus was able to either evolve to create more mutations or revert back to its original sequence following the host shift in mammalian and mosquito cells. It became clear that the DENV in mosquito cells contained significantly more mutations than those in mammalian cells. To compensate for the high viral diversity in mosquitoes, it is able to regress back to its original sequence to be able to survive

in mammals. Although these viral changes appear to be fantastical, Blair expected to find these results. She knew there were more mutations in mosquito cells, but was “surprised at the magnitude of the sequence diversity in mosquito-grown DENV.” To be able to compensate for these vast genomic differences between the DENV in mammals and mosquitoes, the stem loop structures in virus genome RNA (which regulate gene expression) are duplicated so that they can contain both mutations and the original sequence. Researchers hypothesize that this is so that DENV can initially survive in both hosts.

Following this research, Blair hopes to use it to further investigate “the mechanisms that restrict or promote replication of the dengue virus with each of the genome structural conformations we tested in each type of host cell.” Though this research only continues to add to the body of knowledge known on the dengue virus, its evolutionary implications carry much more weight. By realizing that there was a much greater sequence diversity within arthropods they were able to identify one way that helps support the virus's ability to host shift. Hopefully later this research can be applied to other arboviruses, or mosquito-borne viruses, which are forced to constantly adapt so that they can survive in both vertebrate and arthropod hosts. Regardless of the applications of this research, one thing's for sure: this virus and others like it will continue to adapt to be most virulent in multiple hosts. ■

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A RODENT WHODUNIT

BY SAGE WESENBERG, BIOCHEMISTRY, 2019

It was the Great Gerbil. In Asia. With the deadly bacterium.

The Bubonic Plague is one of the most notorious epidemics of all time. In Europe, in the mid-14th century, the "Black Death" killed millions of people across the continent. The disease was caused by the bacterium *Yersinia pestis* and had an extreme capacity to cause harm quickly, and with excruciating symptoms. These symptoms were flu-like, and included black blisters, followed by the formation of infected and swollen lymph nodes the size of an orange, called "buboies." Eventually, the bacterial toxin was released into the bloodstream, causing hemorrhaging, degeneration of muscles and organs, neurological damage, gangrene, and ultimately death in 50-70 percent of the population. It was a hideous disease that tore apart families, initiated terror and hysteria, and continued to spread throughout Europe, Asia, and Africa for 400 years.

Up until very recently, the Bubonic Plague was thought to be caused by rats. It was thought that sick rats from Asia came

to Europe. Fleas living on the rats then transported the plague to humans through an infectious bite, causing the beginning of the epidemic. It is quite easy to blame what most consider to be filthy and ugly creatures. However, new research shows that these unloved creatures may not be to blame.

"PERHAPS THE HISTORY OF ONE OF THE MOST DEMORALIZING EPIDEMICS OF ALL TIMES WILL HAVE TO BE REWRITTEN."

But there is still a rodent at fault. Researchers at the University of Oslo believe it to be the cute, pink-nosed Great Gerbil. These scientists analyzed tree ring records from Asia and Europe to see weather patterns over many years. They were able to conclude that the weather during the years of Bubonic Plague outbreaks would have been too wet for rats to travel from Asia to Europe with

their infected fleas carrying the disease. However, this weather is rather good for gerbils, who can also carry fleas. During this time in Asia, there were wet springs and warm summers, which matches the type of weather that causes huge increases in gerbil populations. These gerbils would have then travelled on trade routes to reach Europe and the Middle East.

This theory, while now quite plausible, still has to undergo further tests in order to be proved. This will be done through DNA testing of European plague victims' skeletons. If scientists are able to see a big variation in the DNA, then that would imply that various outbreaks came from different influxes of the disease coming from outside of Europe, rather than coming from the local rats.

Perhaps the history of one of the most demoralizing epidemics of all times will have to be rewritten. ■

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From Disease Treatment To Designer Babies: *A Slippery Slope*

BY RONAN TALTY, BEHAVIORIAL NEUROSCIENCE, 2017

The story of Neil and Sharon Bernardi is undeniably heart wrenching. The English couple watched their first three children pass away just hours after they were born. Their fourth child, Edward, lived – despite frequent, day-long seizures and other central nervous system abnormalities – until the age of 21. In the meantime, Neil and Sharon attempted to have three more children, all of whom died from complications before reaching two years old. Years passed before the couple learned that their suffering originated from mitochondrial defects present in Sharon's cells.

Mitochondria, dubbed the 'powerhouse of the cell,' are an organelle present in most eukaryotic cells. Their primary function is to generate Adenosine Triphosphate (ATP), the cell's principal source of chemical energy. Unlike most other organelles, mitochondria store their own set of genetic material, distinct from the DNA situated in a cell's nucleus. Although this 'mitochondrial genome' represents only 0.1% of a cell's genetic information, it plays a significant role in development.

In the United Kingdom alone, 150 newborn children per year suffer from life threatening, mitochondrial diseases. These diseases vary in severity from person to person, making them difficult to diagnose, inflicting an array of ailments such as neurological problems, muscle weakness, visual or auditory impairments, heart, liver, and kidney disease, gastrointestinal disorders, and general developmental delays. No treatments exist for the underlying causes of mitochondrial diseases; prevailing treatments serve only to alleviate symptoms and slow the progression of the disease. Fortunately, a solution may finally be on the horizon for families grappling with debilitating mitochondrial diseases.

The United Kingdom recently approved laws allowing scientists to incorporate the genetic material of three people to create

babies free from previously unavoidable mitochondrial diseases. The procedure requires two embryos: a donor embryo, containing the desired mitochondria, and the parents' embryo, bearing the defective mitochondria. The nucleus of each embryo is extracted, and the nucleus from the parents' embryo replaces the nucleus of the donor embryo. This process pairs the bulk of the parents' genetic material, contained in the nucleus, with the viable mitochondria, obtained from the donor. As a result, it circumvents any diseases that would normally arise due to deficiencies in the mother's mitochondria. Since only the mother's mitochondria are typically passed onto the offspring, an alternative method employs the same technique but utilizes egg cells instead of embryos.

While few debate the staggering impact this technique could have on families struggling with mitochondrial diseases, skeptics are wary of the scientific precedent that this procedure might set for the genetic modification of embryos. Critics contend that the legalization of this method is the first step down the 'slippery slope' to 'designer babies.' Invoking images reminiscent of Aldous Huxley's famous novel, *Brave New World*, they claim that scientists and parents will ultimately select for traits such as beauty, athletic prowess, creativity, and intelligence; in tandem, the health benefits of genetic modification would rapidly fall from focus. Alternative arguments against the procedure come from pro-life supporters, along with religious groups in England, who cite the destruction of embryos as a reason not to pursue the technique. They assert that a number of alternatives, including adoption and egg donation, exist for mothers with mitochondrial defects to raise families and that, in light of such options, the procedure is unnecessary.

Although complaints abound, it appears that the majority of scientists support the

technique's implementation and looks forward to its anticipated health benefits. Dr. Eric Stewart, a Genetics and Biochemistry professor at Northeastern University, believes that the slippery slope argument holds no ground and that the procedure will be a huge help to the population that suffers from mitochondrial disease. "Why ban something useful and harmless," he asks, "if there is actually nothing wrong with the technique in question?" Stewart also postulates, from his understanding of the technique, that "any likely side effects will be very small compared to the disease itself." Despite his overt enthusiasm toward the procedure, Stewart makes it clear that he is not devoid of caution in stating that his "concerns fall along the lines of making sure the procedure is carried out with as many controls and as much care as possible." Scientists involved in the technique's execution must work to reduce the probability of error and exercise due care throughout the process. Doing so will garner the trust of the public and maximize health benefits for patients.

With the law in place, British scientists can now move ahead with the procedure. Estimates suggest that the first 'three person baby' could be born next year and as many as 150 English couples could profit from the technique annually. There are still barriers necessary to overcome, however, before the United States can follow suit. Although Stewart concedes that it "is hard to know," he feels that "the biggest obstacles in the U.S. will most likely not be based in science, but in people's beliefs." This past January, at the request of the FDA, the Institute of Medicine commenced a review of its social policy and ethical considerations in relation to the "genetic modification of eggs and embryos to prevent the transmission of mitochondrial disease." Over the next 14 months, the committee will reconsider its policies on the matter and, throughout that time, it remains inevitable that controversy will soar as both sides battle to make their voices heard. ■

EXPANSION MICROSCOPY EXPANDS SCIENTIFIC HORIZONS

BY ALEX CODA, PHYSICS AND MATHEMATICS, 2017

Ever since microscopy entered the scientific scene with the compound microscope in the late 1500s, it has been one of the most fundamental tools of discovery. Immediately scientists were able to make leaps and bounds in our understanding of the natural world. As technology progressed, microscopes allowed humans to see more than ever before. However, even the versatile microscope would one day reach its limit. More specifically, it would reach the diffraction limit; the inherent stopping point of a manmade optical instrument due to angular resolution. But nothing is carved in stone, and three scientists at MIT, Fei Chen, Paul Tillberg, and Edward Boyden have recently conquered this long-thought-to-be absolute limit.

The diffraction limit is a simple fact that tells us that microscopes have a size limit on what they can magnify. This has to do with how traditional microscopes allow visualization: like our eyes, they use light. To see something, the light has to bounce off of it. In our day-to-day lives this is no problem;

there is always light, so we never have the problem of not being able to see things. At the molecular scale, once objects are smaller than a wavelength of light (around 400 nm for visible light), standard microscopes can no longer magnify them to a point we can see. The interesting thing about this limit is it is not one of technology. It is a hard limit based on simple, fundamental physics, which makes it all the more impressive that a group of scientists from MIT have recently found a way around it.

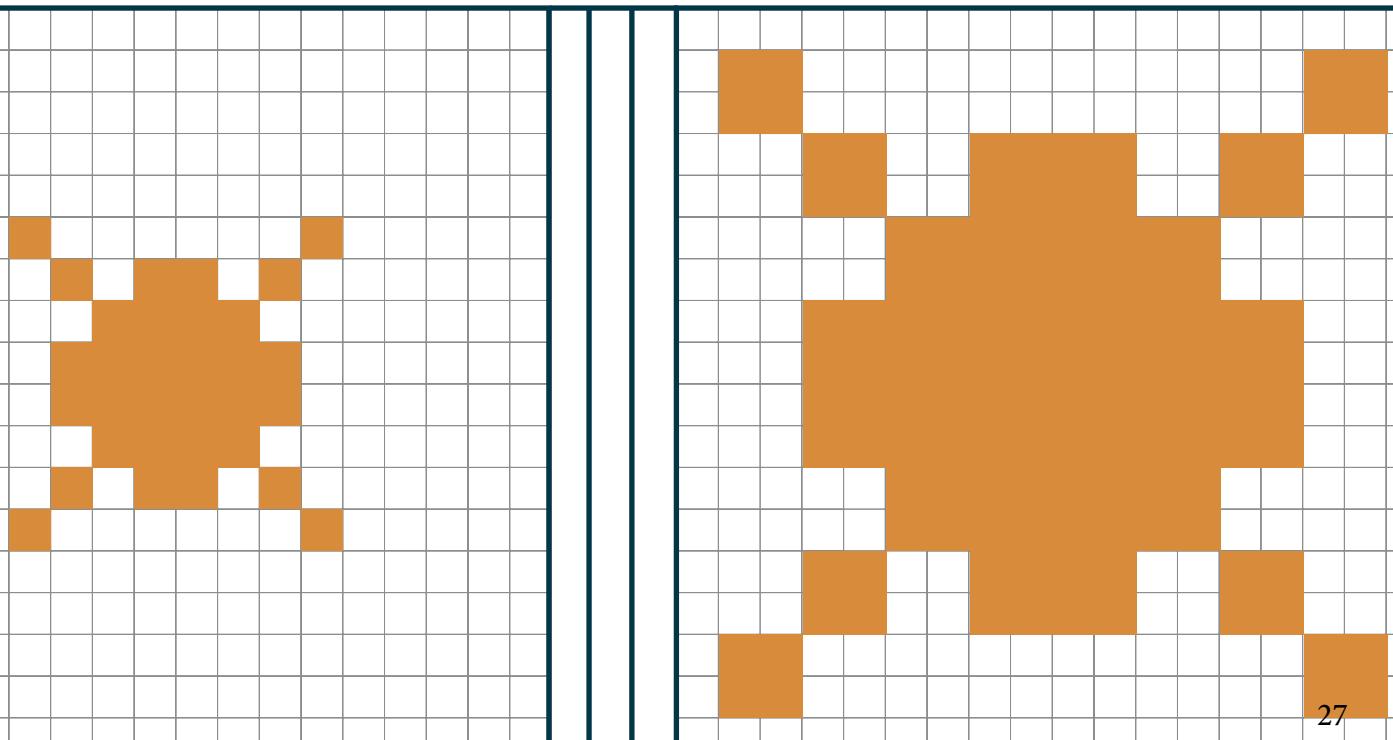
Earlier this year, Boyden and his team at MIT published a paper on a novel technique called expansion microscopy. The idea behind this revelation is basically just what it sounds like. Rather than finding new ways to probe the ultra-small, they take the small and made it bigger. By infusing any desired sample with a certain polymer network, and then expanding these polymers, the scientists can expand an entire tissue sample. Because of the uniformity of the polymers in the tissue, everything expands evenly and the relative sizes and positions

of features remain well preserved, allowing previously invisible details to be visualized.

This discovery is coming in a time of momentous advances in microscopy techniques. Only last year the Nobel Prize in Chemistry went to three scientists and the microscopy technique they developed. While fantastic, their method was relatively costly and complicated, which is a serious drawback. Boyden's new technique has the potential to immediately overcome the Nobel Prize winner as a cheaper and simpler way for scientists to probe the world using visual microscopy.

As humans continue to push the boundaries of physics and technology, there is no doubt that microscopy will remain a relevant and expanding field. The secrets of the microscopic world are not safe for long. ■

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