

March 2015

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INNOVATION

ELECTRICALLY CHARGED SPIDERS

SLOWING DOWN THE SPEED OF LIGHT

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LETTER FROM THE EDITOR

"Innovation" is the buzzword of the year, or maybe the decade. In fact, it might be the buzzword of the century, since the term "innovation" encompasses a variety of disciplines, and can be applied to the unlimited array of new ideas that blossom every single day.

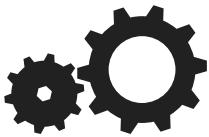
In our first issue of 2015, NUSci explores recent innovation in the sciences: everything from the potential for preventing aging through telomere extension, to budding research on the brain, to a keyboard that can recognize human touch. Maybe the promise of a new drug used to treat depression is what caught your eye, or maybe you picked up this issue because you wanted to find out exactly what trypanophobia is. Maybe you just like the word "innovation" – who could blame you – and were eager to read more about how science and technology will continue to progress in 2015. Whatever your reason, I hope that your reading experience accomplishes that goal.

This issue's theme of "innovation" actually has a double meaning: While our writers have been researching and discussing new scientific ideas, the NUSci E-board has undergone a complete metamorphosis. With a new Head of Design, a revitalized marketing team, and a newly organized squad of editors, 2015 promises to be a transformative year for our organization as well as for the broader scientific community.

It's been a difficult winter, but spring is just around the corner. Whatever your major, now is the perfect time to create something new: to write an article that sparks discussion, to design a groundbreaking product, to solve a particularly complex problem. In short, it's the perfect time for innovation, and I hope that flipping through Issue 23 of NUSci will help inspire you along the way.

Sincerely,

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



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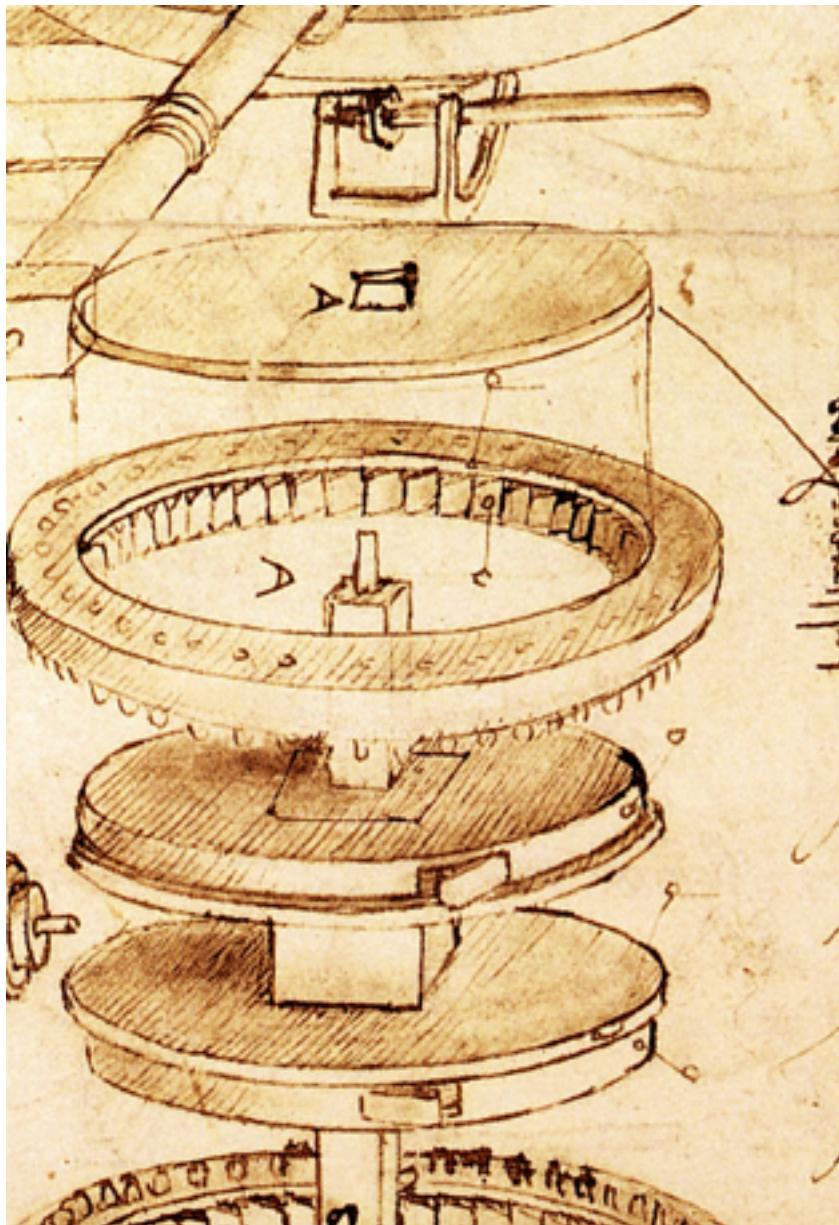
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UPDATING DARWIN

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

Until recently, the best explanation for the origin of life has been a lot of primordial soup with generous helpings of time and luck. This version of the story is plausible but hard to prove and definitely not as elegant as scientists would like. While Earth had elemental foundations and billions of years for life to develop, this does not provide reasoning behind why or how life came about. Biology has taken us back to the simplest recognizable form of life, but to go further it will be necessary to incorporate chemistry and physics to study more fundamental parts of our world. Jeremy England, a physicist at MIT, is currently leading this expedition through his work on the physical principles behind how self-replicating systems develop.

England's work is based primarily on the Second Law of Thermodynamics, which states that the entropy of a system must always increase as time progresses. Over time, matter and energy disperse evenly; entropy is a measure of how far along in this process a system is. The Second Law demonstrates the irreversibility of thermodynamic processes. In Newtonian mechanics, no such law exists; what goes up must come down.

In accordance with the Second Law, a cup of coffee cools down but never spontaneously heats back up. Similarly, a flower grows but never reverts back to being a seedling. This basic reasoning holds for a closed system, one that can exchange energy but not matter with its surroundings. In reality, it is never that simple. The flow of matter in and out of a system creates a situation that is much more challenging to model. The entropy of the universe must continue increasing even

though the entropy of the system itself may not. According to England, this could be the driving force behind the development of life. Living systems, in order to continue existing and self-replicating, must maintain a certain level of organization so they can keep their entropy low. To do this, they must be able to effectively and consistently dissipate energy into their surroundings. England was able to derive a formula that explicitly linked the irreversibility of a transition from one state to another with the entropy production of that transition. Cell division is a common example of this. When a cell splits into two copies of itself, the matter and energy is more spread out, so while the entropy of the cell remains low, the entropy of the universe increases. The chance of this process happening in reverse is very small, effectively zero. This explains why plants grow instead of shrink.

How this principle could explain the development of life is best described through analogy to the theory it is attempting to underlie: Darwin's theory of evolution by natural selection. According to Darwinian evolution, species develop because traits that increase an organism's ability to survive carry through generations while other traits and species die out. Unless there is a change in environment, adaptation is irreversible. The imperative of existence naturally leads to the development of structures able to exist because other, maladaptive traits die out.

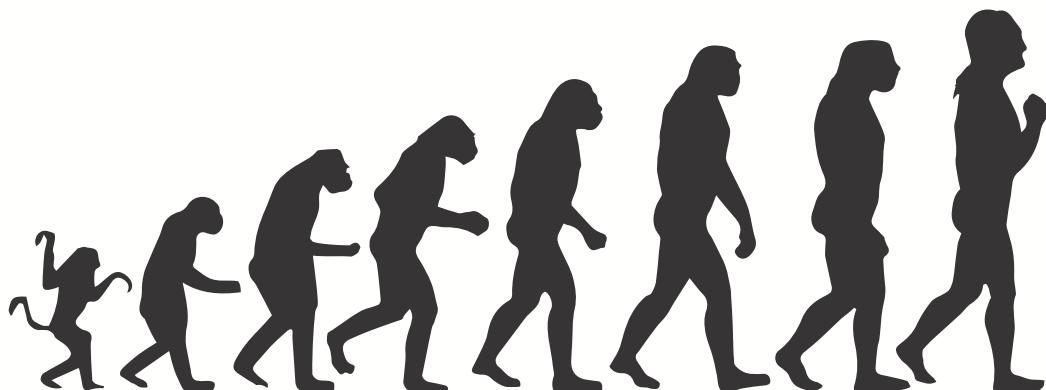
According to England's interpretation, adaptation is reinforced in a similar way at the microscopic scale. Structures that are better able to disperse energy into their surroundings are less likely to revert back to a state that dispels less energy, so the existence of these structures is reinforced.

In Darwin's words, they are more "fit" for survival. Over time, many features that contribute to greater transmission of entropy could theoretically combine and adapt further to make more and more complex structures, eventually creating life as we know it today.

England's equations and theory by no means supplant Darwin's theory of evolution. Rather, they underlie it and fill in some of its gaps. Most importantly, England provides a possible explanation for how the physical constituents of life arranged themselves into the self-replicating structures that we see today. If England's work is proven, it could also help explain some adaptations, such as the complexity of eyes, that have long puzzled evolutionary biologists. While the theory and mathematics are considered valid, it is his interpretation that has the potential to revolutionize the way scientists are able to study life. He has used his theoretical framework to estimate a lower bound on the heat produced by cell division and has demonstrated the existence of self-replicating, inanimate microstructures, but there is still work to be done. Plausibility cannot prove a theory. England's ideas must be tested, and whether or not they are correct, they will be a hot topic for debate in the scientific community for years to come.

Plausibility is not enough to prove a theory. England's ideas must be tested, and whether or not they are correct, they will be a hot topic for debate in the scientific community for years to come. ■

The Journal of Chemical Physics
(2013). DOI: 10.1063/1.4818538.





Tropical Parasites Hijack Cells



BY ASA BUDNICK, BIOLOGY, 2018

Do you live in constant fear of developing cancer? Do you steer clear of alcohol, tobacco, and plutonium? Do tanning salons fill you with a deep-seated sense of dread? If so, you probably won't like the idea of a tick bite infecting you with a parasite that causes white blood cells to behave like cancer cells. Fortunately, unless you are a cow, you don't have to worry.

30 years ago, scientists discovered that some species of the parasitic genus *Theileria* can cause the white blood cells of cattle to act like cancer cells. Only recently has research helped pinpoint the mechanism.

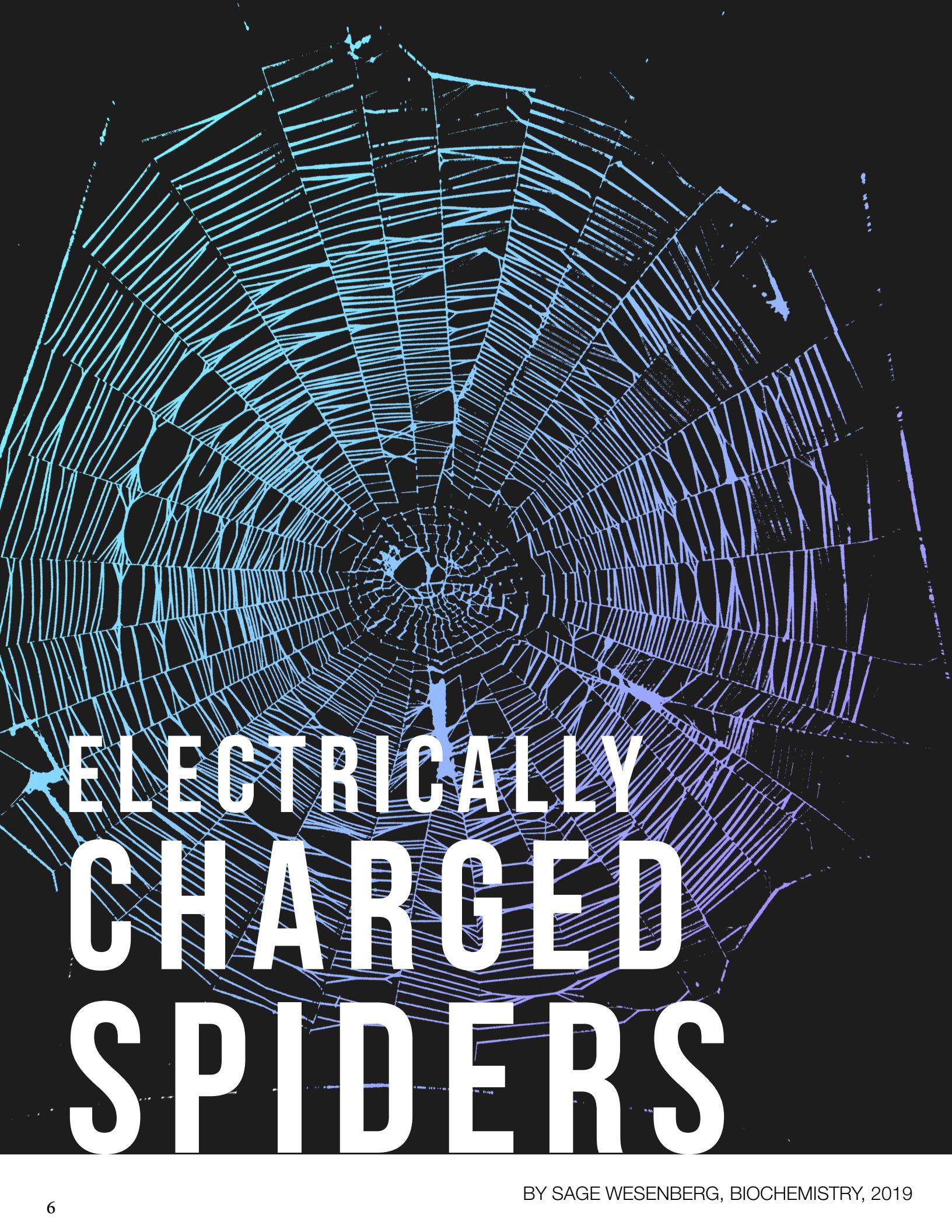
A study published in *Nature* in January details the cancer-causing mechanism of *T. annulata*, a parasite infecting cattle throughout the Mediterranean and Middle East. The study found that a key protein PIN1 lead to increased cell proliferation by targeting the host cell's ubiquitin ligase FBW7. Under normal conditions FBW7

acts as a tumor-suppressing agent by degrading proteins that encourage cell reproduction, specifically the protein c-JUN. In an infected cell, PIN1 released by *Theileria annulata* interferes with FBW7, rendering it incapable of dealing with c-JUN, causing excessive cellular reproduction.

After isolating the mechanism, the researchers investigated possible treatment options and discovered that a drug already in use, buparvaquone, was highly effective at reversing the effects of the PIN1 protein and thus ending the transformation of white blood cells into cancer cells. They found that buparvaquone docks itself in the active site of the PIN1 protein. The scientists determined that the compound Juglone has the same capability. This is an especially handy finding as buparvaquone-resistant *Theileria* strains are becoming more common and cattle losses caused by *Theileria* represent a significant economic loss, over 168 million USD in 1992.

The findings of this study are important for cattle, but they fit into a larger and more important framework of information about cancer. The scientific community has found a number of complex biological links to cancer, including HPV 16 and 18 causing cervical cancer as well as schistosomiasis being tied to bladder cancer. These complex interactions between viruses, parasites, and cancer are incredibly rich with potential for a better understanding of cancer and may ultimately lead to new and improved treatments. ■

Nature (2015). DOI:
10.1038/nature14044.



ELECTRICALLY CHARGED SPIDERS

BY SAGE WESENBERG, BIOCHEMISTRY, 2019

There are thought to be over 35,000 different species of spiders, many of which the scientific world knows very little about. But the ones that are known mesmerize us with their ability to spin silk, a vital component to their very existence. Spiders use silk for a huge variety of purposes, including transportation in the wind, webs, protective nests, wrapping prey, and even as food once it has been used up for other tasks. Most of this silk, or gossamer, is several micrometers thick and starts off as liquid proteins.

This liquid enters a duct where the cell takes water away from the proteins as hydrogen is pumped in. This forms an acid bath that allows a gel to form. From there the unspun silk transforms, becoming a solid fiber as it goes through the spinneret gland. Spinnerets are a key organ in spiders, and are the main plate where the silk is formed. At the end of the silk formation process, the spinnerets release different types of silk, depending on what the spider needs to do with it.

According to a recent study published by *Biology Letters*, there is a more complex process of silk-making carried out by the Cribellate Orb Spider, *Uloborus plumipes*, found in gardens in Hampshire, U.K. Through detailed research using photography, videography and microscopy of adult female Cribellate Orbs, scientists were able to discover one of the most complicated

silk gland systems known. It is called dry capture thread, and the end process allows for nanometer-sized thread that has an electrostatic charge. This helps catch prey with stickier silk without having it be thicker.

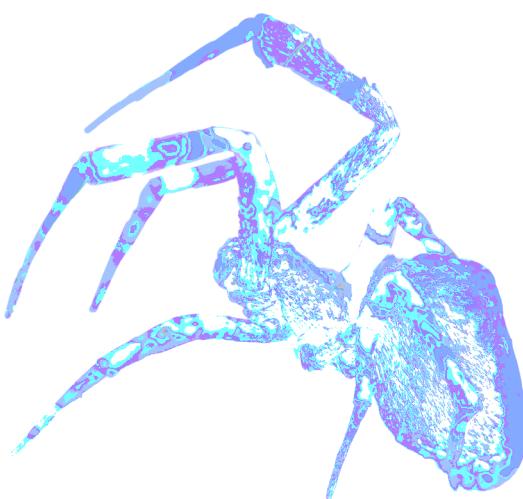
Cribellate Orbs are named after the cerebellum, which is a special silk spinning organ separate from the spinnerets. It is a large plate covered in thousands of spigots that release the threads of silk. This allows for a direct spinning system. The Cribellate silk has a low viscosity, allowing it to remain a liquid for a longer time. As the liquid fills the spigot, its unique ridged shape adds to the pliability and stability of each thread. This is necessary because as the silk exits the spigots, it solidifies in milliseconds, but during that time, the spider uses its hind legs to create a remarkable charge. This is called the "hackling" motion. The hairs on the spider's hind legs comb the threads and clump the filament up into bunches. This simultaneously creates electrostatic friction and makes the thin silk extremely sticky.

In the separate chambers of the duct where the liquid pools, there are spaces at the end to hold extra reservoirs of remaining liquid silk to help distribute the forces of energy of the combing which happens very rapidly and forcefully. The extra liquid acts as a buffer to ensure that the forces will not damage something so thin. Simply put, the dry capture thread

system combines thousands of filaments, just nanometers in diameters, that fly out of individual spigots at a rapid speed where they are pulled apart with the spider's legs to "fluff them up" into microscopically wooly puffs, creating the electric charge.

This is important for the spider and its ability to survive, but it also gives us some clues about creating very thin fibers that have a large stretching capacity. With this information about this unique spider, scientists should be able to learn more about the connections between fiber dimensions and their mechanical properties, helping them to develop nanotechnology to help with polymer-processing, where sticky nano-sized threads could be useful. These English spiders really are quite amazing. As the only spiders of their kind, they have given great insight into creating these electrostatic interactions. ■

Biology Letters (2015). DOI: 10.1098/rsbl.2014.0813.



REPATRIATING CLEAN TECH INNOVATION

BY CAYMAN SOMERVILLE, ENVIRONMENTAL SCIENCE, 2017

Historically, incremental problem solving has led to technological innovation. In the 19th century, the incandescent light bulb was a failure. Even after Thomas Edison developed a practical electric light bulb that could be commercialized, it took over 40 years for utilities to stabilize and for it to be regarded as a successful invention. Today, the incandescent light bulb is, once again, a failure. Modern energy innovations are rapidly edging out 19th and 20th century technologies, and each new technology—like LEDs—is defined by critical problems and crucial defeats. Thomas Edison himself famously stated, “I have not failed. I’ve just found 10,000 ways that won’t work.” In between the lines of our history

books (or that Wikipedia article) there is the un-said notion that from failures researchers learn and eventually develop a product that changes how the world works, creating a ripple effect in every industry. The challenges they face are the defining origins of innovative thinking.

Both the developed and the developing world face critical energy challenges that will require an interdisciplinary solution, incorporating the private sector, politicians, government, engineers, scientists and entrepreneurs. Recent data released by the International Energy Agency (IEA) outlines what has been described as the “inevitable demise of the fossil fuel empire.” Essentially, we have reached peak oil—the maximum

rate that petroleum can be extracted. Rising demand and production costs drive rising electricity costs, which affect the cost of every product that is manufactured, transported or sold. Energy companies are beginning to acknowledge the death of the fossil fuel industry, recognizing that our critical energy needs pave the way for the inevitable rise of clean energy. In a 2014 report, the U.S. Department of Energy (DOE) stated, “America is experiencing a historic shift to a cleaner, more domestic and more secure energy future. That clean technology revolution is here today, and it is gaining force.”

DRIVERS OF TECH INNOVATION

The energy landscape of the U.S. is in the midst of a dramatic transformation. In 2014, the DOE released a report—“Revolution Now: The Future Arrives for Four Clean Energy Technologies”—outlining revolutionary technologies that have achieved dramatic cost reductions and have been adopted within the clean energy industry. Augmenting the exponential growth of clean energy technologies are catalysts that originate from the recognition of a problem like the clean energy crisis, and strengthen the competitive advantage of companies focused on clean energy.

In 2009, President Barack Obama invested more than \$4 billion in funding to modernize the energy grid. This was quickly followed by the largest oil spill in U.S. history, which led to increased media attention on global climate change and a growing commitment to reducing greenhouse gas emissions. The compelling statistics of the latest Intergovernmental Panel on Climate Change (IPCC) illustrate a clear necessity that global leaders develop approaches to mitigate climate change. In the midst of climate summits about horrifying emissions statistics, the Obama administration and

the Environmental Protection Agency (EPA) proposed a mandate that power plants restrict carbon dioxide emissions by 30 percent by 2030. By early February 2015, this had become a pillar of the president’s climate agenda, as he advocated for tighter restrictions on oil and gas drilling and proposed a \$4 billion Clean Power State Incentive Fund to bolster federal awards for clean energy programs. Obama’s recognition of the unavoidable effects of global warming is evident in his latest budget proposals, which focus on investment in clean energy solutions.

The EPA’s plan faces criticism from the coal industry because it places generators that emit little or no carbon in a more favorable position in the electricity marketplace than high emitters, like coal. The EPA administrator, Gina McCarthy, stated: “By leveraging cleaner energy sources and cutting energy waste, this plan will clean the air we breathe while helping slow climate change...” The new budget plan provides \$7.4 billion to be invested into clean energy and climate science research and development, demonstrating

government policies and investment can help drive clean energy innovation.

Thirty years after the first federal solar facility was launched by the U.S. Department of Energy, today known as the National Renewable Energy Laboratory, solar panels cost only 1 percent of their original price. More than 60 years after the first silicon solar cell, the solar industry is a thriving contributor to the hundreds of billions of dollars in economic activity generated by the clean energy industry.

The growing need for innovative technology to solve our global climate needs is evident through breakthrough technology in the Massachusetts clean energy industry, funded by universities like Massachusetts Institute of Technology (MIT). According to the DOE, there is “tremendous opportunity for countries that invent, manufacture and export clean energy technologies,” which is expected to continue to grow.

CLEAN TECHNOLOGY AND THE FUTURE

In 2009, Vice President Biden delivered a progress report on how recent policy changes encourage alternative sources of energy and the transition to a more efficient, cleaner economy. Whether that's through improving the efficiency of fossil fuel plants or dispatching renewable energy sources, there

is an ongoing need for innovative technology. Revolutionary technologies such as wind power, solar PV molecules, and electric vehicles (EVs) are becoming a more viable, cost-effective part of the total clean energy market. These technologies pave the way for the future of the clean energy industry.

ONSHORE AND OFFSHORE WIND

The DOE's investments and efforts in technological advancement have enabled the "emergence of larger, more cost-effective" land-based wind turbines. Newly developed turbines are taller with longer blades, allowing them to function in lower wind conditions. In 2013 the average new U.S. wind turbine had a "310 percent increase in the blades' swept area," compared to the 1998-1999 period. In addition, the energy generation capacity of a single turbine has more than tripled in the U.S. since early

2008, which has contributed to a reduction in the cost of wind energy. According to a recent DOE report, wind continues to be "one of America's best choices for low-cost, zero carbon, zero pollution renewable energy," with the total potential of both offshore and land-based wind representing about 49,700 TWh –approximately 10 times today's U.S. electricity consumption. Wind power is predicted to meet up to 20 percent of the U.S. electricity demand by 2030.

SOLAR ENERGY

The manufacture of solar panels has increased along with wind development. Federal incentives and government investment in solar photovoltaic (PV) research are accelerating the rise of the solar industry, which has already advanced the industry's progress by 12 years. In 2014, the U.S. Agua Caliente solar project came online in Arizona, making it the world's

largest PV power plant and advancing America's stance as a global leader in solar development. Solar energy has the potential to become the largest energy resource on Earth. While modern solar technology fails to solve intermittency and storage issues, the cost-competitiveness of the resource is expected to increase with technological breakthroughs and commercialization.

ELECTRIC VEHICLES (EVs)

While the U.S. deployment of EVs is expected to increase, the cost of each battery (\$/kWh) will decrease with continued development of innovative batteries. Analysts say that the cost of battery storage has will

have reduced by at least one fifth by 2020. The Obama administration is investing \$16 billion into developing the "Vehicles of the Future," pledging to construct three electric vehicle factories and 28 battery

CONCLUSION

Fossil fuels are a finite resource, and are increasingly unable to support the seven billion inhabitants of our planet and the infrastructure that is built up around them. Though 2015 looks nothing like Back to the Future predicted it would, there is increasing support for clean energy companies and their technologies, which has driven remarkable innovation in the clean energy industry. Furthermore, universities, the private sector and the government are funding outrageous technologies that

are not well known, including but not limited to solar roadways, space initiatives, see-through solar and tofu solar. In short, a clean energy revolution is taking place across America, underscored by the steady expansion of the U.S. renewable energy sector. There is tremendous economic opportunity for the countries that invent, manufacture and export clean energy technologies, and so the clean energy industry is expected to continue to grow rapidly in the coming years.

Energy Innovation By the Numbers



15X

more solar PV installations than 6 years ago



\$4 bil

spent by Obama towards solar & geothermal energy and a modernized grid



26%

expected US emissions decrease by 2025

manufacturing factories by the end of the year. There is potential for an increase in EV dual charging stations in the City of Boston's initiative, "Go Boston 2030", which aims to revolutionize the city's transportation system.

Responsible development of all of America's rich energy resources -- including solar, wind, geothermal, bioenergy and water -- is an important part of President Obama's Climate Action Plan and will help ensure America's continued leadership in clean energy. Moving forward, the Energy Department will continue to drive strategic investments in the transition to a cleaner, domestic and more secure energy future. ■

THE DEATH OF INNOVATION

BY KRISTEN DRUMMEY, BEHAVIORAL NEUROSCIENCE, 2016

The National Institutes of Health functions both as a center for cutting edge medical research and as a benefactor for hundreds of thousands of researchers across the country. Researchers depend on grants from the NIH for their own livelihood and that of their labs. Recently, the NIH funding well has been going dry. The NIH budget stagnated during the past decade, and the government-mandated sequestration in 2013 brought even more cuts to its deflated budget. A scarcity of grants translates to fewer research projects being funded, especially those proposed by young scientists who are new to the field. Something must be done to supplement the NIH budget, and Senator Elizabeth Warren believes she has the answer.

Cuts in NIH funding have reverberated throughout the scientific community for years now, but the situation has seemed particularly bleak following the recession of 2008 and subsequent sequestration in 2013. The sequestration slashed budgets across nearly all government-funded programs. As a result, the NIH budget lost nearly two billion dollars, which essentially eradicated about 650 grants that it was able to fund the year before.

The impact of decreased federal funding on researchers is significant. Young scientists fresh out of graduate school are finding it more difficult to get jobs, and if they do find a position it is nearly impossible for them to get a federal grant. Established scientists are afraid to propose daring and innovative ideas, as funders like the NIH could perceive them to be too risky and therefore not worthy of grant money. Scientists in general are spending too much time rewriting and revising grant proposals that will likely not get accepted, and aren't spending enough time actually thinking about science.

Elizabeth Warren, one of two Democrats representing Massachusetts in the Senate, believes that she has a solution to the problem. In late January, Warren introduced

the Medical Innovation Act. Warren's solution calls for what she dubs a "swear jar" for Big Pharma. Repeatedly, large pharmaceutical companies find themselves at odds with the government about laws that they may have overlooked during the year. Warren suggests that when these companies break the law, they have to put some of their profits towards a fund benefiting the NIH and FDA.

Warren's plan makes it clear that it would not be an extra tax imposed upon these businesses, but rather a means of keeping them accountable and incentivizing against law-breaking. The act would only fine companies that sell "blockbuster" drugs that rake in over a billion dollars a year in sales. The legislation would further ensure that the money would only go toward funding radically innovative or fundamental research, or towards research grants for young, emerging scientists.

"THE NIH FOUND A 5% DECREASE IN ITS BUDGET, WHICH ESSENTIALLY ERADICATED ABOUT 650 GRANTS THAT IT WAS ABLE TO FUND THE YEAR BEFORE."

While the Medical Innovation Act would certainly add funds into the dwindling accounts at the National Institutes of Health, many people have voiced concerns about how it would do so. Pharmaceutical bigwigs argue that their large companies gain little from NIH-funded research, and therefore it would be foolish to have them pay into NIH funds. Other critics say that the prospect of losing profits to the government may deter companies from settling, and instead produce drawn out legal battles that benefit nobody.

Unfortunately, alternative solutions to replenishing NIH funding are scarce. People ranging from patients to graduate students

to physicians have been lobbying Congress for years to increase the funding, and more groups are joining in the fight. Act for NIH: Advancing Cures Today is one such group that is hoping to convince lawmakers that the NIH budget crunch is approaching a crisis. However, Congress seems to agree – the problem lies in creating a plan and finding the money to supply a steady budget for the NIH. And according to Act for NIH's president, Patrick White: "Do we have a plan? Do we have a legislative proposal for how we're going to fix this? We do not."

A perspective piece published in the Proceedings of the National Academy of Sciences suggests that the problem within the biomedical research field is not one of money at all, but rather stems from systemic problems that need to be addressed before ample funding becomes a possibility again. Their proposed solution includes reducing the amount of students that enter into Ph.D. programs and increasing the number of staff scientists in labs, who would be responsible for a variety of projects but wouldn't necessarily need a degree as time consuming as a Ph.D. While this plan would likely reduce stress on the system in the long term, its short-term effects could be extremely detrimental to aspiring graduate students and currently operating labs and investigators.

Whatever the true reason is for the shortage of funding, it is a complicated problem whose solution is of the utmost importance. When scientists are denied the time and flexibility to truly think about the problems society faces, innovation dies. The "publish or perish" mentality that has arisen out of fewer positions and scarce funding is slowly strangling the once great American research system. While Warren's plan may not be the only or the best solution to the problem, it is certainly a welcome take on a complex issue that desperately needs to be solved, and soon. ■

The Fountain of Youth

Scientists Slow Cellular Aging Through Telomere Extension Procedures

BY OLOLADE AKINGBADE, BEHAVIORAL NEUROSCIENCE, 2017



Since the beginnings of human civilization, man has assumed the quest for a cure to an inevitable and inescapable reality: old age. This search for the 'Fountain of Youth' dates back to time of Alexander the Great and the 16th century Age of Exploration, and has persisted in modern times through the \$260 billion anti-aging industry. While creams, lotions and pills may ameliorate the wrinkled skin and puffy eyes that accompany aging, the effects are superficial and fleeting at best, doing little to address the progressive decline of tissue function that results in mortality.

A major biological cause of the cellular decline that accompanies aging is the shortening of telomeres on chromosomes. Chromosomes, structures made of DNA and proteins in the body that code for our genetic material, are protected by telomeres, caps at the ends of chromosomes that have repetitive nucleotide sequencing. Telomeres serve as protection during DNA replication; as they shorten, they act as a buffer from truncation of coding genes. Telomerase reverse transcriptase (TERT) is an enzyme that reverses the progressive shortening of chromosome telomeres by adding repeating sequences to the ends of telomeres. Even with TERT's regenerative activity, telomerase shortening becomes progressively faster than telomerase lengthening with age. Once telomeres reach a critical length, cells no longer continue to divide. This cellular process then coincides with a continued decline of organ functioning and aging-related diseases such as cardiovascular disease and arthritis.

Research on lengthening telomeres and anti-aging has been on the rise since 2009, when a cohort of scientists received a Nobel Prize for their research on telomere regeneration. American scientists Elizabeth Blackburn, Carol Greider and Jack Szostak are responsible for discovering the enzyme telomerase and its activity in protecting and regenerating telomeres. Nothing has been as groundbreaking in aging research until recently.

In January 2015, a research group at the Stanford University School of Medicine announced the discovery of a new procedure that efficiently lengthens human telomeres in skin cells. The procedure uses modified messenger RNA to lengthen human telomeres up to 1000 nucleotides in length, turning back the internal clock in cells that limit the rate of their division and use in a laboratory setting. The modified messenger RNA uses TERT, a sequence present in telomerase that promotes telomere longevity. Although TERT has previously had a negative immunological influence on cells, the researchers found that treated skin and muscle cells replicated up to 40 times more than untreated cells. The lab's work is remarkable, as most telomere extension research from this past decade has had minimal influence on telomere length.

John Ramunas, a postdoctoral researcher at Stanford University, states: "Previous attempts to deliver mRNA-encoding TERT caused an immune response against telomerase, which could be deleterious... our technique is non-immunogenic and acts over just a few days to reverse telomere shortening that occurs over more than a decade of normal aging."

The research team hopes that the new messenger RNA and TERT procedure serves as an impetus for more effective telomere extension in anti-aging research. Their work serves as a basis for future research on treating aging-related diseases and genetic illnesses that occur through telomere shortening. Head Stanford researcher Helen Blau notes that "one day, it may be possible to target muscle stem cells in a patient with Duchenne muscular dystrophy, for example, to extend their telomeres. This has really opened the doors to consider all types of potential uses of this therapy" (4). While telomere lengthening through TERT is not exactly the 16th century promise of a fountain of youth, it is a significant start to aging-related disease treatment. ■

The FASEB Journal (2015). DOI: 10.1096/FJ.14-259531.

BRAIN: COLLABORATION, INNOVATION, AND MEDICATION

BY RONAN TALTY, BEHAVIORAL NEUROSCIENCE, 2017

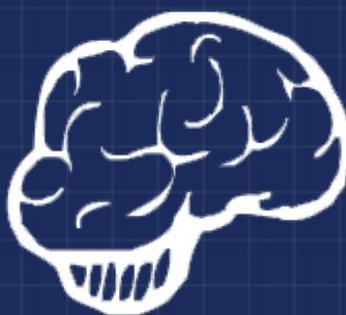
The human brain is arguably the most complicated object in the known universe. For that reason, it's incredible to think that neuroscience is still a relatively new field. Santiago Ramón y Cajal only published his Neuron Doctrine, the foundation for modern neuroscience, in the late 19th century. Just over one hundred years later, scientists can already facilitate telepathic communication, reconstruct images channeled through a person's visual cortex, and enhance the cognitive ability of mice by providing them with human brain cells. In medicine, neuroscientific discoveries continue to advance the treatments of illnesses including neurodevelopmental disorders, mood and anxiety disorders, and neurodegenerative disorders. When it comes to the brain, however, scientists still possess more questions than answers.

In April 2013, President Barack Obama unveiled Brain Research through Advancing Innovative Technologies (BRAIN): a 10-year government initiative to construct a comprehensive, real-time map of the human brain and its activity. This map would depict how individual neurons interact with one another, revealing how the brain's electrochemical processes dictate our behaviors, and generating new methods to identify, treat, and prevent brain disorders. The project outlines two main phases: the first emphasizes the development of more sophisticated, necessary technologies and the second plans to utilize those developments for discovery-driven research. Scientists estimate that technological advancement will peak after five years and, while research will not halt prior to this period, the bulk of scientific discovery will occur afterwards, with the new technologies fully integrated into laboratories.

The initiative, amidst technological progression and research, will also encourage advancements in theory, computation and analytics to interpret the surplus of data expected from the scientists. The National Institute of Health (NIH),

Defense Advanced Research Projects Agency (DARPA), the National Science Foundation (NSF), and the Food and Drug Administration (FDA) are at the project's forefront as momentum continues to grow.

Labeled as the Human Genome Project of Neuroscience and drawing parallels to the first moon landing and the atomic bomb's development, there is little debate regarding BRAIN's potential for creating overwhelming, groundbreaking science and health impacts. President Obama also cites the initiative's capacity to enrich the economy, recalling that, "Every dollar we invested to map the human genome returned \$140 to our economy." Critics, however, posit that the increased funding for neuroscience laboratories will hamper progress in other equally important fields. Others claim that BRAIN represents a far more complex task than the Human Genome Project.



The brain's 100 billion neurons and their 100 trillion continuously changing synapses considerably trump the human genome's 20,000 genes and, as of now, no scientist has documented the activity of more than a few simultaneously – even with invasive probes. Finally, unlike the Human Genome Project, BRAIN remains largely open-ended and lacks tangible objectives. Some critics claim that without any concretely planned deliverables, the project will inevitably fail to reach its anticipated heights. Francis Collins, director of the NIH, only fueled this criticism when he stated that the initiative

"[doesn't] as yet have a clearly laid out set of scientific milestones and goals."

Even in the face of these criticisms, scientists involved in the initiative are optimistic about the project. Dr. Cori Bargmann, a neural circuits professor at Rockefeller University and co-chair of the NIH committee tasked with planning BRAIN, claims that what enthuses her most about BRAIN is "its collaborative nature" and "the way it has brought people together from neuroscience, engineering, molecular biology, and computational and theoretical backgrounds." She also says that the initiative's emphasis on advancing equipment has made her "more excited about the nuts and bolts of technology development." With BRAIN's support, Dr. Bargmann and her laboratory plan to tackle undertakings such as building new microscopes customized for specific objectives.

BRAIN launched its first round of funding in September 2014 and the NIH alone announced grants for 58 projects totaling \$46 million. Funding will only increase in the years to come with President Obama ready to commit \$200 million next year and private research foundations such as Google and General Electric also preparing their own sums. In the meantime, revolutionary technologies are in development. Dr. Brefczynski-Lewis of West Virginia University, one beneficiary of the funding, is formulating a wearable, helmet-like PET scan device. Another NIH grant recipient, Dr. Maunsell of the University of Chicago, is designing laser technology to direct the firing of neurons and study how groups of neurons generate behavior. Dr. Bargmann imagines that projects like these "will allow us to observe the brain in more natural conditions." While it will likely take ten years to develop the science to a point where it is ready for medicine and pharmaceutical companies to utilize, BRAIN's first round of funding offers the field its first glimpse at an exciting, unified neuroscientific future. ■

CHEMISTS DISCOVER A NEW TYPE OF CHEMICAL BOND

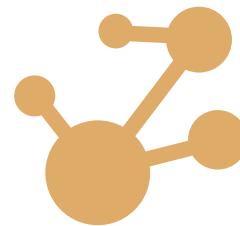
BY MARC TAWFIK, BIOCHEMISTRY, 2018

Chemistry students, look out - soon there will be another type of chemical bond to learn about in lecture. Dubbed the "vibrational bond," its existence has been sought after since 1989 when a team from the University of British Columbia first observed a reaction violating an expected trend.

Traditionally, increasing the temperature of a chemical reaction should cause the reaction to occur at a faster rate. However, this was not the case when Donald Fleming and his team exposed muonium, a lighter and radioactive variant of hydrogen, to bromine gas in 1989. For the ensuing chemical reaction between muonium and the bromine gas, it was observed that a decrease in temperature actually caused the reaction to speed up. Puzzled, Fleming proposed that as the muonium and bromine atoms interacted, "they formed an intermediate structure held together by a 'vibrational' bond" - a concept that had already been proposed earlier that decade. In a vibrational bond, one of the lighter muonium atoms would rapidly migrate between two heavier bromine atoms, "like a Ping Pong ball bouncing between two bowling balls," describes Fleming. Unfortunately at the time, Fleming could not test his hypothesis, as existing technology could not monitor the incredibly brief reaction closely enough.

However, due to recent technological advances, Fleming and colleagues were able to run the mysterious reaction once again at the Rutherford Appleton Laboratory in England with more conclusive results. In his new paper, published in December 2014, Fleming explains that the properties of vibrational bonds involve a unique relationship with a value called zero point energy- the amount of energy molecules would retain if at absolute

that exists before the bromine and muonium atoms bond completely. Ultimately, this effect is responsible for the observed decrease in the speed of the reaction between bromine and muonium at higher temperatures that had first puzzled researchers in 1989.

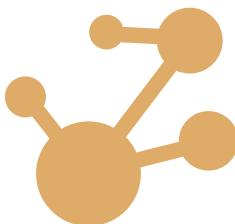


"THE PROPERTIES OF VIBRATIONAL BONDS INVOLVE A UNIQUE RELATIONSHIP WITH A VALUE CALLED ZERO POINT ENERGY."

zero (0K). Typically, chemical bonds are formed by trading potential energy for small increases in aforementioned zero point energy. However, Fleming explains that the opposite is also possible: a decrease in zero point energy can be traded for an increase in potential energy to form a chemical bond, or more specifically, a vibrational bond.

Using advanced computational modeling, Fleming's team determined that when muonium and bromine react, a large gain of potential energy at the expense of zero point energy could indeed be detected, confirming the existence of the vibrational bond. Furthermore, the vibrational nature of the bonds between the muonium and bromine atoms had the effect of lowering the energy of the intermediate compound

It remains to be seen whether vibrational bonds can be observed in other reactions between chemical substances. Fleming predicts that vibrational bonds likely exist in other reactions involving a combination of light and heavy atoms, such as that between bromine and muonium. Although the possible future applications of the work of Fleming and his team remain unclear, this new finding has certainly shaken up the world of chemistry, something that is likely to be reflected in classrooms everywhere. ■



Journal of Chemical Physics (1989). DOI: 10.1063/1.457435.

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BREACHING THE BLOOD-BRAIN BARRIER

BY MARTA PALERMO, BEHAVIORAL NEUROSCIENCE, 2016

The central nervous system is an incredibly indispensable and necessary feature within our body. The environment that surrounds it is often one that is carefully and perfectly regulated, as even the slightest change could affect its functioning abilities. The central nervous system is made up of two major components: the brain and the spinal cord. Both of these are safely secured within their own layers of protection. However, the brain's protection - the blood-brain barrier (BBB) - has some exceptionally unique features.

The BBB is a wall-like feature that isolates the brain tissues from specific substances circulating in the blood stream throughout the vascular system. In technical terms, it is a diffusion barrier that allows only small specific water and lipophilic molecules to more freely access the brain, all led by the concentration gradients of the entering molecules.

Think of the human body as a country. Every region has organs with designated functions and connections to other nearby systems. The head is like the capitol: Washington DC. The brain is, therefore, the White House equivalent. In real life, the White House has several layers of security surrounding it; so does the brain. Again, the blood brain barrier acts as the filtering fence that surrounds the brain. Theoretically speaking, only selected personnel with the appropriate badges or some other sort of approved recognition are allowed entrance to the White House. No drones or knife-wielding maniacs get through (cough, cough). Just like the White House, but perhaps with more accuracy, the blood-brain barrier only allows certain molecular structures in, those that have a badge or, even better,

some sort of flag to recognize them by.

Due to its known tight composition, the BBB is advantageous yet inconvenient.

The inconvenience arises when the blockade creates obstacles to the drugs and proteins intended to treat neurologically based disorders, such as Alzheimer's and brain cancer. It is the issue linked to the permeability of the BBB that has interested many researchers such as Henry Daniell, a published professor from the University of Pennsylvania, to focus their studies in trying to find a way to render the needed drugs permeable to this highly selective membrane.

Daniell and his team began their study by trying to find a way to breach the BBB in order to administer the necessary protein that is part of an Alzheimer's treatment discovered in a previous study. Symptoms associated with Alzheimer's disease show up with the presence of specific plaques in certain areas of the brain. Researchers seem to believe that the protein A β , amyloid beta often found in soluble form in healthy individuals, and in tangled form in patients with Alzheimer's, is what causes the dementia associated with the disease. Professor Daniell and his team seem to have found a protein that degrades A β , called myelin basic protein, or MBP. This is all great and exciting until the time comes to administer this protein to Alzheimer's patients and the protein is blocked outside of the blood-brain barrier due to its chemical composition. This is where the cholera toxin B protein (CTB) comes in. For the purpose of this example, the CTB protein fundamentally acts as a badge, or the flag that is chemically modified and attached to the MBP, in order to accompany it through the BBB and into the brain's environment.

Initial tests were led on healthy mice. The animals were fed capsules of freeze-dried leaves that had been genetically modified to express the CTB-MBP compound along with a GFP (green-fluorescent protein) whose sole purpose was to track the glow of the protein inside the organisms. The glowing protein compound was found to be both in the brain

and the retina, meaning it had crossed both the blood-brain barrier and the retinal-blood barrier (a similar layer of protection found in the retina). To see if the protein compound worked on the actual A β plaques, Professor Daniell and his colleagues exposed the CTB-MBP protein to a population of the brains of mice bred to have Alzheimer's. Using a staining protein that binds to the brain plaques, they found that the exposure to their compound protein CTB-MBP resulted in a 60 percent reduction of staining, meaning that the A β tangles were dissolving. Through collaboration with the National Institute of Health, the team of scientists obtained brain tissue from people who died of Alzheimer's and performed the same staining procedure. These last results showed a 47 percent reduction of staining in the parietal cortex, a brain area found to be significantly important in the development of Alzheimer's-associated dementia.

The researchers continued their tests by administering CTB-MBP-containing capsules to 15-month-old (the equivalent of roughly 80 human years) mice bred to develop Alzheimer's disease. After three months of exposure to the oral administration of these capsules, the mice had a reduction in A β plaques of roughly 70 percent in their hippocampus and up to 40 percent in the cortex, while their control group counterparts, fed with CTB-MBP-less lettuce leaves, showed no evidence of reduction of brain plaques. The research yielded results that show the correlation of Alzheimer's patients also having plaques in their eyes. The researchers, however, found that as expected, the mice with Alzheimer's did have plaques in their retinas and that those that were fed the CBP-MBP compound showed the consecutive reduction of A β retinal tangles.

"No one knows whether the memory problems that people who have Alzheimer's disease are due to the dementia or problems with the eyes. Here we show it may be both, and that we can dissolve the plaques through an oral route," Daniell said. His achievements have paved the way for new neurological drug treatment administrations, and thanks to his advanced research and tests, scientists will now approach drug design in a new way. ■

Molecular Therapy (2014). DOI: 10.1038/mt.2013.273.

A TRYPANOPHOBIC DIABETIC'S DREAM: TEMPORARY TATTOO USED TO DETECT GLUCOSE LEVELS

BY GAURI NARAYAN, BIOLOGY, 2018

Monitoring sugar levels in those that suffer from diabetes is extremely important. Diabetes, a disease which causes high blood glucose levels in victims, is due to either an insufficient production of insulin or a lack of response to insulin in the body's cells. This renders the cells unable to use glucose and transfer it to energy. In the past, the methods used to consciously track blood sugar levels throughout the day were painful and irritating, as blood had to be sampled from the fingertip through the use of a pricking device. When it comes down to having to test your glucose levels several times a day, the finger-pricking technique is certainly not ideal. This is particularly true for trypanophobics, also known as people with a very real fear of needles. The mere idea of having to take a sharp object to the finger multiple times a day would drive many trypanophobics away from the process completely, and for those that have diabetes, this could have dangerous consequences.

However, the scientific world has recently taken a technological step forward with the help of principal researcher and engineer Amay Bandodkar and his team from the Department of NanoEngineering at the University of California, San Diego. Bandodkar and his team have developed a convenient method of monitoring blood-glucose levels, and the best news is that it does not involve breaking skin whatsoever. A study in *Analytical Chemistry* about the innovative design describes it as an "epidermal diagnostic device." The sensor is placed on the skin in the same way a temporary tattoo is, and it measures glucose through a scientific process known as reverse iontophoresis. Simply

put, this involves the transfer of molecules through the skin so that the internal levels can be detected and monitored.

Reverse iontophoresis uses a small electrical charge applied to the skin that leads to the flow of major ions, such as sodium, from the inside of the body to the electrodes of the device. The positively charged sodium ions move towards the cathode, bringing with it what is known as interstitial fluid. This interstitial fluid located in the skin tissue contains glucose molecules. The biosensor contains an enzymatic feature that then identifies the precise levels of glucose through the electrical charge that is produced and measured by the device, all without ever having to penetrate the skin's surface.

Although products created before the biosensor claimed to adopt the same non-invasive method, they have fallen short of their promises. One example of this is the GlucoWatch, produced by the company Cygnus. The product is a watch that sits on the wrist and uses the same method of iontophoresis to detect glucose levels, suggesting that the GlucoWatch beat Bandodkar's team to the punch. However, the fine print on the patient information slip for the GlucoWatch product indicates that it isn't as perfect as it sounds. It clearly states that the GlucoWatch is "not designed to replace your regular blood glucose meter," and that it should be used in addition to, not instead of, a finger-pricking device. The product also has been known to cause skin irritation in those who use it on a regular basis, likely because of the level of electric current that is used to attract the interstitial fluid to the electrodes.

These particular issues were directly addressed in the new temporary tattoo sensor, taking it one step ahead of products like the GlucoWatch. To combat the issue of skin irritation, the sensor uses a slightly weaker electrical current, and a hydrogel is applied to the electrode as a barrier between the skin and the device. In investigative tests, this was shown to eliminate the issue of redness and itching altogether. The main experiment that was done to test the sensor involved human volunteers who wore it and periodically had it measure their glucose levels. The measurement from the biosensor was then analyzed against results from finger-pricking devices, in order to test the accuracy of the readings. The results of the on-body study indicated that the biosensor was very accurate in depicting fluctuations of glucose in the blood, particularly after subjects ingested carbohydrate-rich meals. Therefore, the tattoo-like sensor could be a more reliable non-invasive method than other products currently on the market.

The development of the temporary tattoo sensor is an incredible step forward in the technological world. The sensor itself is conducive to everyday use, and its low cost of less than \$1 per sensor is an added bonus. At the moment, the initial experiments have proven the accuracy and capability of the product, and only time will tell if widespread use around the world will reflect the same. For now, diabetics with trypanophobia around the world should thank Bandodkar and his team and breathe a sigh of relief. ■

Analytical Chemistry (2015). DOI: 10.1021/ac504300n.



the ETYMOLOGY of **INNOVATION**

BY GWENDOLYN SCHANKER, JOURNALISM AND BIOLOGY, 2018



Innovation is a term that is used over and over, whether it's to describe a new scientific discovery, changes to a business model or an original creative idea. Although the technical definition of innovation is to "make changes to something established, especially by introducing new methods, ideas or products," according to the New Oxford American Dictionary, "innovation" as a buzzword encompasses a much broader set of criteria. Inevitably, people of varying ages and fields of study define innovation differently, but one thing is certain: it's motivational. It's the kind of word that keeps researchers going and catches a reader's eye. It's the kind of word you can dedicate an entire issue of a science magazine to, but still give writers free reign when it comes to topics.

The term "innovate" comes from the Latin word *innovare*, which means to "renew, restore, or change." However, innovation in a modern context generally refers to a brand-new invention or discovery – the process of creating something out of nothing. Synonyms to "innovation" include "originality," "ingenuity," and "upheaval" – hardly the same as "renewal." Clearly, there's more to innovation than its etymology and its dictionary definition, so how does one define what makes something "innovative"?

For first-year chemistry major Alexis Hester, innovation is all about improving peoples' day-to-day lives. "It means making things better so that people's lives can be easier," she said.

Third-year health science major Brandon Bairett expressed a similar opinion, saying that examples of innovation he'd encountered often consisted of "new technology coming out and bettering what we already have."

Both Bairett and Hester felt that their definition of innovation might be different than that of someone in a different field of study.

"It depends on what you're focused on," Bairett said. "Your brain is wired differently if you're a business major, versus a science major."

While the definition of innovation necessarily varies for different disciplines, there's a desire for an interdisciplinary definition of innovation, one that applies to all different areas of study. A 2009 paper led by Anahita Baregheh of Bangor University in Bangor, U.K. attempted to find such an integrative definition of innovation by collecting over 60 definitions of the word from seven disciplines, including business and management;



economics; and science and engineering.

After performing a content analysis on the data they collected – i.e. differentiating each definition by its disciplinary orientation, determining which terms were most often used, and so on – the research team developed a diagrammatic definition which they described as follows: “innovation is the multi-stage process whereby organizations transform ideas into new/improved products, service or processes, in order to advance, compete or differentiate themselves successfully in their marketplace.”

This definition emphasizes the fact that the important part of innovation does not necessarily lie in the end result, but in the process of creating something new. The goal of the study was to design a definition that enables “the development of common meaning and shared understanding of the various dimensions of innovation,” a necessity in an increasingly globalized society. However, it could still be argued that every discipline requires its own definition of innovation, and that the term “innovative” is defined on a case-by-case basis.

That's certainly what Hester and Bairett thought, although surprisingly, when

asked to provide an example of a recent innovation, their choices were the same. Both students cited the contents of a recent publication in *Nature* that described the results of drug discovery research by Northeastern University Distinguished Professor Kim Lewis and Professor of Biology Slava Epstein. Using funding from NovoBiotic Pharmaceuticals, which the two scientists co-founded in 2003, the researchers synthesized a new antibiotic that they termed teixobactin, which kills pathogens without encountering detectable microbial resistance, by growing uncultured bacteria using a device called the “iChip.”

The research was groundbreaking in multiple ways: for one, the bacteria Lewis and his team of researchers grew had previously been viewed as “uncultivable” – it seemed as if the microorganisms were impossible to grow in the lab. Using the iChip, the scientists were able to sort individual bacterial cells into chambers, after which they covered the device with a semipermeable membrane and placed it back into the soil, which allowed the bacteria to grow in a more natural environment than a petri dish.

This new method of developing uncultured microorganisms led to the discovery of multiple new antibiotics, although one single compound – teixobactin – seemed the most promising. Sure enough, after conducting trials of teixobactin in mice, the researchers found that the compound attacked serious pathogens such as *Staphylococcus aureus*, but did not encounter any of the traditional viral mutations that lead to antibiotic resistance.

“I was fairly confident that resistance would develop sooner or later,” Lewis said,

stating that the one of the major aims of the drug discovery process has always been to develop more antibiotics quickly to counteract bacterial resistance. “Now there is another possibility for doing something very differently, and that is developing compounds that don’t develop resistance.”

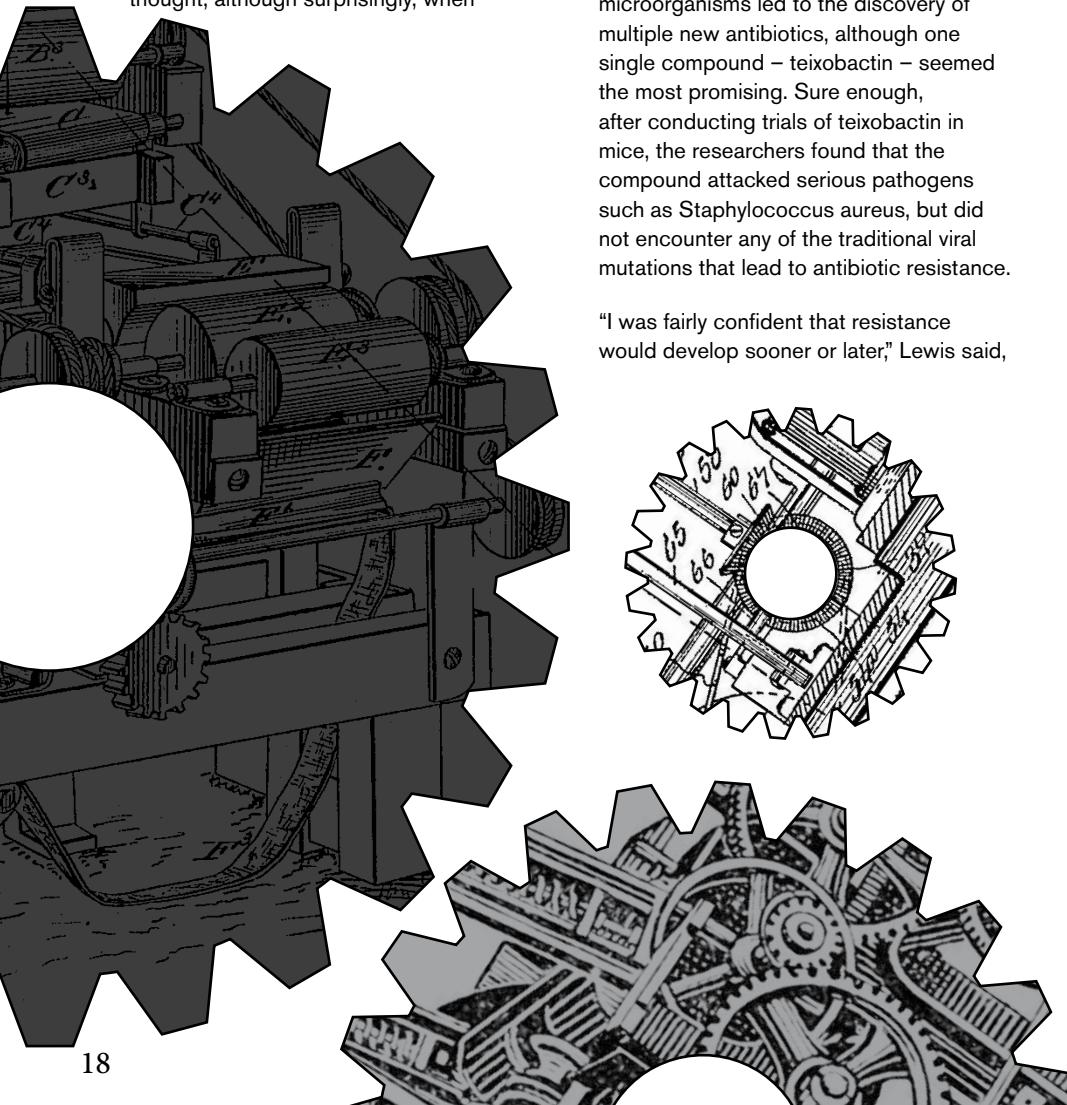
Furthermore, the method of using the iChip to access uncultured bacteria can be used more widely, giving scientists access to an entirely untapped world of bacteria that could in turn be used to develop further antibiotics. The double whammy of the promising properties of teixobactin and the ability to cultivate previously uncultivable bacteria sets a high standard for the definition of innovation, and it certainly fits with the definition provided by Baregheh and her colleagues.

Lewis defines innovation in two different ways – disruptive innovation and more quantitative, evolutionary innovation, the latter of which is measured by “how forward a discovery brings us into the future from where we are now.”

“If the problem you are attacking is highly significant and you have moved the field forward to an extent that is impressive and has not been anticipated, that is perhaps a serious innovation,” he said.

While Lewis insists that it is not his position to say whether the paper in *Nature* represents “innovative” or “groundbreaking” research or not, he loosely cites it as an example of disruptive innovation, which is often used by venture capitalists, and, in Lewis’s own words, “disrupts the current paradigm or dogma.” This idea of “disruption” provides juxtaposition between the concept of innovation as a “renewal” of an existing idea or product, and defining innovation as the creation of something completely original.

In addition to his research alongside Epstein and his colleagues, Lewis cited another example of disruptive innovation: the introduction of new methods for whole human genome sequencing by synthetic biologist Craig Venter. Venter favored the concept of “shotgun sequencing,” which involves sequencing long DNA strands by dividing them into small fragments, which are then reassembled to generate the overall genomic sequence. This is an alternative method to the “chain termination” method of DNA sequencing, which can only be used for shorter strands. Venter sought a faster method of genome sequencing and, by providing funding to Celera



Genomics, created a new, innovative approach to the Human Genome Project.

"It sounded totally crazy, but he pulled it off, and that's what fueled the genomics revolution," said Lewis.

Innovation is a malleable concept with a constantly changing and evolving definition. While Lewis and his team's research may represent the epitome of innovation at Northeastern right now, soon enough another 2015 innovation will materialize that will lead researchers and students alike to rethink the definition once again.

It's still uncertain what the main innovation trends for 2015 will be, but avid news readers can count on "innovation" being continually used as an important buzzword in the media with regards to business, economics and scientific discoveries. With the help of multidisciplinary definitions of innovation such as that developed by Baregheh and her colleagues, as well as individual disciplinary definitions used by Lewis and other Northeastern researchers, the general public can continue to develop an understanding of innovation and appreciate the invigorating process of innovating, rather than the end product.

When it comes down to it, the important thing about innovation isn't its definition. It's the feeling behind the buzzword; it's the process of moving society forward, or the act of "disrupting" the current paradigm, as the case may be. It's all about the excitement scientists experience when they create something from nothing, or in many situations, something better, more useful, or faster than something else.

Hester put that feeling simply. "I think it sounds like you're working really hard," she said of the use of the term "innovation" to describe research like that of Lewis and his colleagues. "It makes what you're doing sound cooler. It's got a good connotation."

Lewis's response was very similar, although he described the feeling from a researcher's standpoint rather than a student's.

"There's a larger practical utility to motivate," Lewis said. "For people like myself – for scientists – [the goal of innovation is] to do something that we find exciting. The fact that this is going to be useful – that's wonderful, but that's not the primary motivator. It's the excitement of doing this." ■

Emerald Group Publishing (2009). DOI: 10.1108/00251740910984578.

Nature (2015). DOI: 10.1038/nature14098.

**"the
goal of
innovation
is to do
some
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that we
find
exciting"**

- Professor Kim Lewis



Photos courtesy of Bureau Skateboards.

As awareness of the importance of environmental sustainability grows, environmental catastrophes have been increasingly brought to the attention of the U.S. The Great Pacific Garbage Patch—a collection of marine debris in the North Pacific Ocean highly concentrated near Japan and in between Hawaii and California—is one of these disasters.

The Patch is not actually an island of trash floating in the ocean. Instead, the cloudy, soupy, areas are made up almost entirely of bits of plastic called microplastics, intermixed with larger items such as fishing gear and shoes. In fact, 80 percent of the debris that makes up the patch comes from land-based activities in North America and Asia. As no single nation will take responsibility for the lack of proper recycling procedures or provide funding to clean it up, the Great Pacific Garbage Patch and other lesser-known patches across the globe continue to grow.

That's where 2007 Northeastern alumnus Ben Kneppers stepped in. While spending time in Australia as a consultant, Kneppers

first befriended Lehigh University alumnus David Stover, a fellow surfer with a degree in mechanical engineering and an interest in sustainability. After moving to Santiago, Chile to work for Fundación Chile in 2012, Kneppers recognized an opportunity to help Chilean communities with plastic waste collection, especially in places where recycling programs are limited.

“BUREO SKATEBOARDS ARE MADE PRIMARILY OUT OF FISHNETS AND OTHER DISCARDED FISHING GEAR FOUND OFF THE COAST OF CHILE.”

Originally focused on creating plastic collection programs to prevent additional plastic waste from entering the ocean, the plan evolved into developing products to support the funding of the collection programs. The team was made up of surfers and skaters, so it makes sense that the

GARBAGE TO GRIND

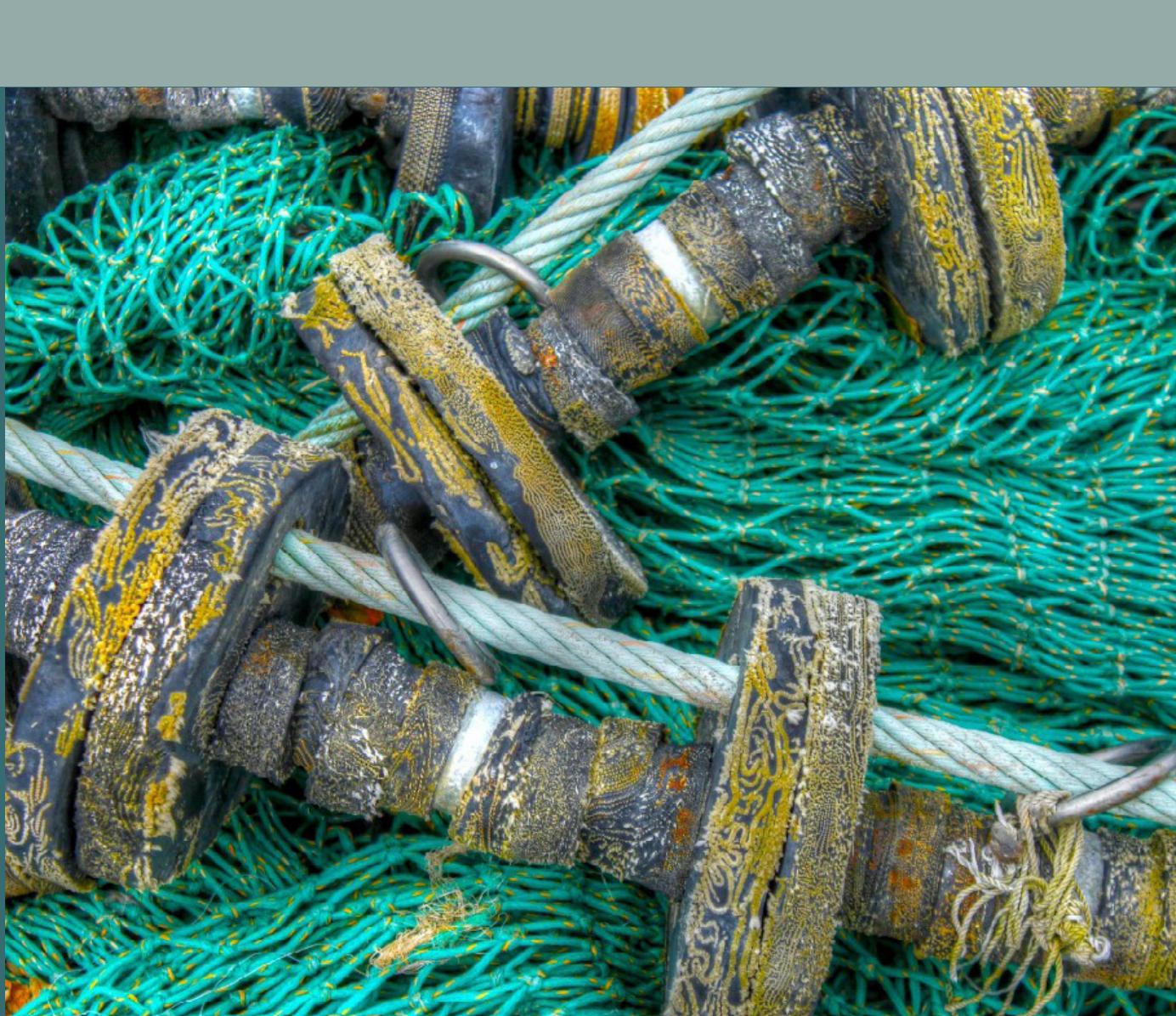
NU GRAD'S STARTUP MAKES SKATEBOARDS FROM THE PACIFIC GARBAGE PATCH

BY ASHWINI RAO, BIOCHEMISTRY, 2018

innovators chose to make a skateboard out of the excess plastics. In 2013, Kneppers, Stover and their long time friend David Ahearn co-founded Bureau Skateboards: a company that aims to reduce the plastic pollution along Chile's coastline by molding excess detritus into skateboards. The idea was accepted by Start-Up Chile—a government sponsored accelerator program that provides startups with \$40,000 to put their plans in motion. The project was also awarded \$10,000 from IDEA, Northeastern's student-run venture accelerator.

Bureau Skateboards are made out of fishnets and other discarded fishing gear found off the coast of Chile. In the facility, the nets are sorted, shredded and pelletized. The pellets are then transformed into a skateboard designed in the shape of a fish.

To create their skateboards, the team established a mutually beneficial relationship with Net Positiva, Chile's first ever fishnet collection and recycling program. Net Positiva provides fishermen with environmentally sound disposal points, and Bureau collects them to



convert the recyclable and durable raw materials into a valuable product.

Bureo doesn't work alone. When interviewed by Transworld Business in 2014, Kneppers described his excitement to team up with Satori Movement, another business with a green approach. "We are very proud to have Satori wheels on our boards, which have 100% recycled cores and a formula containing 30% vegetable based oils," Kneppers explained.

Bureo Skateboards are now sold primarily in local skate shops across the coast of Chile and in a couple of Patagonia locations in Southern California \$150 each. Still, the trio is looking towards the horizon and setting new goals. They want to expand business across the U.S., generate increased awareness for

the project, and organize beach clean ups with local partners in California.

Kneppers credits Northeastern with helping him develop his entrepreneurial spirit and passion for sustainability. On one co-op, he worked in Zambia with a soccer team to help raise awareness about AIDS/HIV safety. The group purchased a former bar and converted it into a community center to educate young people. Kneppers said, "I got to walk out of Northeastern with an incredible resume and worldly experiences that let me find what my deeper passions were." ■

A KEYBOARD THAT KNOWS YOU

BY MEGAN PINAIRE, MARINE BIOLOGY, 2018

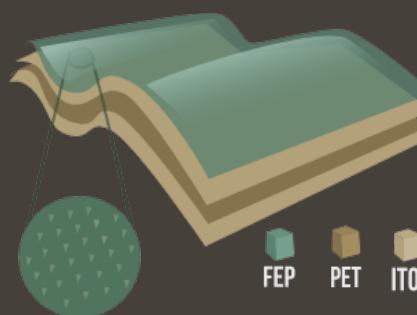
Cyber criminals have a concerning presence in modern society; identity theft, password theft and cybercrime within businesses are all major issues. Students' computers and laptops are stolen on university campuses more often than one might think. Of course, many of these laptops are password protected, but what happens if someone knows or figures out that password? For many people, one password gives access to everything from Facebook to bank accounts.

A newly invented self-powered and self-cleaning keyboard created by Georgia Tech Professor Zhong Lin Wang and his graduate research assistant Jun Chen can eliminate the stress of password theft and subsequent cyber-criminal activity, all while charging a phone. Best of all, the electricity to power it is free; it all comes from the electrostatic charges in the user's fingers.

Everyone remembers rubbing a balloon on their clothing and then "magically" sticking it to the wall. Rather than magic, this is caused by a phenomenon called contact electrification and occurs when any two dissimilar objects come into contact and then separate from each other. Less obviously than with clothing and a balloon, it also happens when fingers type on a keyboard.

Wang and Chen's keyboard's general structure is made up of a plastic base, two indium tin oxide layers, a polyethylene terephthalate layer and a top layer of fluorinated ethylene propylene. All of these are materials used commonly in the electronics industry, but have been combined and built in a new way. When a typing person's fingers touch the electrode material covering Wang and Chen's keyboard, current is generated. Then, the triboelectric effect (a type of contact electrification), paired with the electrostatic induction effect, generate voltage and produce a small charge over the keyboard as the fingers type over it.

This "intelligent" keyboard operates on the pairing of contact electrification and electrostatic induction. Its base is plastic, with transparent film materials vertically stacked on it. By sandwiching a layer of polyethylene terephthalate between two indium tin oxide (ITO) layers, top and bottom electrodes are produced. The ITO surface is then covered by fluorinated ethylene propylene (FEP), which acts as the electrification layer when touched by typing fingers. Through a combination of contact electrification and electrostatic induction, a positive charge is created when electrons transfer from the skin to the keyboard material as fingers type on the FEP.



This positive charge on the top electrode is induced when the fingers move away from the FEP. Consequently, a negative charge occurs on the bottom electrode. Now, imagine a person typing an essay on this keyboard, causing these positive-negative charges over all of the keys. This creates a temporary electric field over the keyboard with electrons flowing freely between the two electrodes. This electricity generated through typing on the keyboard is what makes it a self-powered device, with no batteries needed on wireless keyboards. The electricity is enough to charge small devices like cell phones, iPods, or the transmitter needed for wireless keyboards.

Convenience aside, the keyboard has the potential to create biometric security

on the associated computer. Orthodox keyboards are strictly mechanical and work by recording which specific key is pressed. The new, "intelligent" keyboard records the pressure of each keystroke as well as the latency between each key press. Such information is unique and specific to every individual. Thus, if a roommate tried to break into her friend's computer, this keyboard would recognize that the roommate's typing was too slow or that she was pressing the keys too hard, and would not allow access to the computer, whether or not the password entered was correct.

To prove the keyboard's ability to decipher between users, the team recorded the electrical patterns of over a hundred people typing the word "touch" four times. It turned out that the keyboard was able to discern individual typing pressure and speed with a low margin of error. As another type of test, the team poured all different kinds of liquids, dirt, and oil on the keyboard, with no damaging effects. Since the original foundation is a sheet of plastic, liquids do not ruin it. In fact, the surface coating the keyboard actually repels the grime. The other materials used to build the keyboard are common, inexpensive materials. Thus despite the high tech qualities of Wang's intelligent keyboard, he believes its durability and cost will be able to compete in the market with regular keyboards. ■

ACS Publications (2014). DOI:
10.1021/nn506832w.

MACAQUE MONKEYS MAKING MASSIVE MILESTONES

BY NATASHA MATHUR, BEHAVIORAL NEUROSCIENCE, 2018

Picture a scenario: a man jogging in the park, headphones in, focusing on hitting the ground hard with each step. Suddenly, he notices his shoelace is untied. As he moves to the side of the path, dread sets in and he wonders "Will I be able to do this?" As he kneels down, and attempts to tie the shoelace one arm does not move like the other. He is unable to properly grip the shoelace with one hand, and he struggles to tie the lace using just one hand. Why? Because one arm is a prosthetic. Although the ability to control prosthetic limbs has increased in the past few years, it is still difficult for amputees to accomplish mundane tasks like tying their shoes, or picking up a coffee mug. Recently, scientists from Germany published a paper in the *Journal of Neuroscience* revealing a new experiment that may change the lives of those with prosthetic arms.

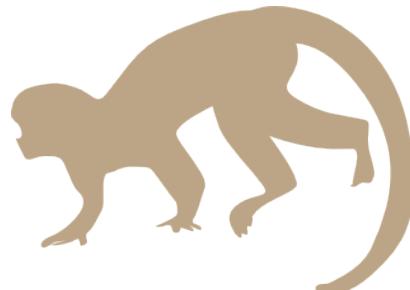
It is hard to believe that in the world of flying cars and 3D printers the development of better prosthetics has moved so slowly. However, because the brain is such a complex organ, it is difficult to make the proper connections, or synapses, that allow fine motor movements. It takes children years to pick up fine motor movements (a perfect example is how writing skills progress well into the teen years), so it makes sense that these robotic arms and legs cannot move freely. It takes a lot of physical therapy and practice to use a prosthetic limb, and even then those who have them are faced with many difficulties. There are a million little everyday tasks that seem so natural to us, but also require so much precision and control. People with prosthetic hands undergo the very difficult challenge of having to learn control all over again.

The scientists in the study focused on the cerebral cortex, which is highly developed and is responsible for motor movements. A part of the cerebral cortex, known as the parietal lobe, deals with sensory information

that can be visual, tactile, or auditory. There is a region in the parietal lobe called the anterior intraparietal (AIP), which contains neurons that respond to the shape of an object, as well as its orientation. This allows the eyes to see the object and the brain to understand the object relative to the person, so that coordinated movements can be made in order to grasp the object. The scientists focused on specific areas of the AIP, known as the F5 and M1, which focus on taking the visual representation of the object and making the correct motor movement. For example, when one sees a coffee mug, the brain knows to grasp the handle of the mug so that the fingers curl around handle and the thumb rests on top. Although the AIP is not very large, it is a very important region of the brain because it signals which grip is appropriate for each object.

measured brain cells is strongly dependent on the grip that was applied. Based on these neural differences, we can calculate the hand movement of the animal." Once the hand movements were calculated, the specific configurations could be transferred over to a robotic hand. The robotic hand was then able to perform these grips.

This innovative way of thinking has the potential to change the lives of people with prosthetics forever. When the connection between the brain and the limb is gone, people will still be able to perform tasks via this robotic arm. The arm has many degrees of freedom, meaning that all of the joints can move at specific angles that current prosthetics are unable to reach. There are many people who end up with prosthetic arms and are forced to learn to use one hand for everything. They are unable to bend their joints and maneuver their hands the way they used to, which is an added stressor to a difficult transition. However, this robotic arm will allow people to do more and to live like they used to. ■



Once the scientists successfully targeted the brain area, they gave two Macaque monkeys various tasks. The monkeys wore a special glove that recorded the movements made by the hands and fingers and were trained to remember the shape and size of specific objects prior to beginning any recordings. The objects were items like cylinders with different widths, rings, and cubes. In order to properly ascertain which neurons were being activated, the monkeys did the task in the dark so the neurons activated by the visual could be ignored. Each monkey did each task ten times. According to the first author of the paper, Stefan Schaffelhofer, "The activity of the

The Journal of Neuroscience (2015). DOI: 10.1523/JNEUROSCI.3594-14.2015.

KETAMINE AND DEPRESSION

BY JOSE COLOM LAPETINA, BEHAVIORAL NEUROSCIENCE, 2017

Major Depressive Disorder has been an affliction long before scientists found an appropriate term for the condition or developed medicine to treat it. In the roughly 4,000 years since Mesopotamians used the word "Melancholia" to describe an affliction that affected mood and overall disposition, we have gotten a few inches closer to solving the problem, as the development of modern medicine and the field of neuroscience have shed light on this old puzzle. While we no longer believe that demonic possessions or evil spirits cause this illness, there is still much to learn as to how depression develops and operates.

In the mid 1960s, a theory of depression became popular and widely accepted. This theory stated that depressive symptoms were the result of imbalances between neurotransmitters – the chemicals your brain cells utilize to communicate and modulate mood and behaviors – and that treatment that could target these symptoms in attempts to regulate them would prove successful. This led to the development of the current drug, which focuses on restoring imbalances between neurotransmitters known as monoamines by acting upon the receptors neurons used to recognize them. However, drugs that target monoamines have been criticized for delayed onset and inability to treat an estimated 59 percent of patients who suffer from depression. This, along with a growing body of evidence from more sophisticated assays, points to a new theory of depression that involves genetic factors, a potential role for stress, and the possibility that the cause of depression may lie downstream. This has poked holes in the monoaminergic theory and left a need for a more complex explanation.

As our understanding of the breadth of Major Depressive Disorder improves and we grow closer to comprehending the mechanisms that underlie it, it is essential that we move away from treatments based on older observations and put all efforts into seeking out more effective methods of alleviating depression. The last decade presents a growing body of work pointing to the Glutamate neurotransmitter system as a likely

candidate for treatment because of their role in communication between brain regions. The glutamatergic system is a fast-acting network of signaling that is involved in many important cerebral processes, most notably memory and learning. A spotlight has been placed on NMDA glutamate – the major excitatory neurotransmitter the aforementioned system utilizes for communication - because of this lasting important effect on higher cortical function. As a result, one drug is getting a lot of attention: ketamine.

expressed rapid decrease in scores on the SSI throughout the duration of the four hour-long study. These famous results led others to attempt to duplicate these results and sparked interest in the apparatus behind the drug's therapeutic effect.

These advantages, however, are accompanied by some drawbacks. First, it is noted that while the drug does provide rapid alleviation of depressive symptoms in patients with depression, relapse is common and the relief is somewhat short-lived. Other roadblocks include the possibility of developing psychosis after prolonged use, the potential for misuse outside of the hospital setting, and monitoring administration will be a difficult task that some institutions might not want to bring upon themselves. Perhaps the factor that has set back trials and studies on ketamine as potential treatment is the inability to truly conduct blind testing, as ketamine is a hallucinogen with known dissociative effects that make effects quite difficult to mask.

"THE SUBJECTS... EXHIBITED IMPROVED DEPRESSIVE SYMPTOMS IN AS LITTLE AS 72 HOURS."

The anesthetic ketamine has become notorious as a powerful muscle relaxant and party drug. What is less known is that the drug was suggested as a possible treatment for depression as early as the 1990s, when buzz of the potential therapeutic benefits of ketamine began to grow, and in the early 2000s when the first placebo-controlled, double blinded study evaluated the efficacy of ketamine as a treatment for major depression. The study consisted of randomized patients suffering from major depression being administered a subcutaneous dose of ketamine for two days. The subjects that received the subcutaneous injection exhibited improved depressive symptoms in as little as 72 hours, as opposed to the 4-5 weeks of onset for more traditional anti-depressants.

Another factor worth mentioning is that ketamine's rapid and substantial improvement of depressive symptoms could prove incredibly beneficial in treating patients with suicidal thoughts. An open label study of 33 patients suffering from stubborn depression were infused with (0.5mg/kg) of ketamine while their responses were recorded in accordance to the Scale for Suicide Ideation (SSI) at different time intervals. The individuals participating

The aforementioned setbacks point to ketamine being most useful in situations in which a patient is in need of a fast-acting cure for symptoms for fear of causing harm. Ketamine may be a long ways off from joining the medical arms cache, but future research is warranted as to finding the exact mechanism behind the mitigation of depressive symptoms and finding ways to sustain the antidepressant effect. ■

PubMed (2015). DOI: 10.1111/nyas.12646.

ARE NEW NEURONS HERE TO SAVE US?

BY JORDYN HANOVER, BEHAVIORAL NEUROSCIENCE, 2017

Neurogenesis is the birth of new neurons. This complex process involves three stages: activation, proliferation and maturation. In the brain, specific neural stem cells can, upon activation, proliferate, or rapidly multiply, and will then mature into fully functioning new neurons. There are two specific areas of the brain which are important for memory, the dentate gyrus, and its encompassing hippocampus. Such areas are notable for their high population of new neurons. Their dysfunction can be attributed to the causation of many different psychiatric disorders. Damaging or removing portions of the hippocampus have been proven to induce animal models of mental illness. With less area devoted to the hippocampus, patients are more likely to be suffering from disorders like depression and schizophrenia. Due to the vast amount of pharmacological drugs and treatments that target the hippocampal area in order to combat psychiatric illness, a multitude of research has been done with respect to the effects of neurogenesis on mental diseases.

Depression subsists as the highest researched mental disorder with regard to neurogenesis. Many drugs and treatments typically used for depression have been shown to induce neurogenesis in adults. These drugs can target different neurotransmitters, such as serotonin and dopamine, but ultimately still have the same effect: an increase in new neurons. One question that continue to surface about depression is why antidepressants do not produce an immediate effect. This prolonged process has been supported by the neurogenesis hypothesis; it takes approximately two weeks for neural stem cells to mature. If antidepressants work to cause neurogenesis, then it is theorized that after the antidepressant has been administered for a certain length of time new neurons will have time to augment and become active. This theory thus hypothesizes that the maturation and survival of new neurons is critical to the effectiveness of antidepressant treatment.

As noted in several studies throughout the last few years, anxiety and depression appear to be related – the occurrence of one tends to indicate the other. As such, any effects that neurogenesis have on depression should be considered to have similar effects on anxiety. However, certain classes of drugs used to treat anxiety may react differently than those used to treat depression. In some instances certain drugs had the adverse effects on neural activation, resulting in a decrease of new neurons. Because of the varied results, it has been suggested that medications used for anxiety may alter the functioning of new neurons when exposed to a stressor and should be accounted for when used in conjunction with antidepressants.

allow researchers to insert cells in order to undergo neurogenesis, or attempt to induce the birth of new neurons. Looking on the horizon, it may be possible to determine the links between aging and decline in cognitive ability with regard to neural birth disruption.

Neurogenesis has also been implicated in several other processes including learning and epileptic seizures. Because the hippocampus is involved in memory, learning new tasks will spark activation – specifically in neurons born in the adult hippocampus. Seizures have also been shown to both induce and inhibit proliferation (cell dividing) depending on when they occur over the course of a lifetime. Recent data also suggests that adult-generated neurons are involved in the emotional aspects of hippocampal processing, which relates both to learning and to certain areas of mental illness.

“DEPRESSION SUBSISTS AS THE HIGHEST RESEARCHED MENTAL DISORDER IN RELATION TO MENTAL ILLNESS”

Another significant illness that many studies have sought to explain using neurogenesis is schizophrenia. In young animals it has been shown that removing a portion of the hippocampus significantly decreases the ability to birth new neurons when it reaches its adult stage. Similarly, certain genetic mutations will also render neurogenesis inept. The diverse effects that various schizophrenia-inducing genetic mutations have on neurogenesis may help researchers eventually understand how to help accommodate for the absence of such genes and treat schizophrenia.

Neurogenesis has also been considered for illnesses where there is memory loss. It has been shown that the formation of new neurons decreases with age in the hippocampus, which could be a possible factor in the cognitive deficits related to dementia. This is of sizable importance because further studies will

Amidst the adult brain there are only a few select structures that have the ability to produce new neurons. Within these structures, limited amounts of new neurons are created, which proves to be a small fraction in relation to the total number of neurons in the area. But for the last two decades, research has shown a high level of interest in these cells. They are considered hot topic research regarding mental illnesses, and are affected by various drugs that are used to treat these psychiatric disorders. With the questions surrounding neurogenesis, its causes and the overarching effects growing and pushing to the forefront, it is clear that though this population may be small, it is most definitely mighty. ■

Neuropsychopharmacology (2014). DOI: 10.1038/npp.2014.230.

The Journal of Neuroscience (2008). DOI: 10.1523/JNEUROSCI.3798-08.2008.

Slowing Down THE SPEED OF LIGHT

BY EMILY ASHBOLT, BIOMEDICAL PHYSICS, 2017

There has been much talk of the possibility of exceeding the speed of light, but for a group of scientists from Scottish Universities Glasgow and Heriot-Watt, the last two and a half years have been focused on the exact opposite of that goal. In a paper published in *Science Express* in January, the team of scientists took a deep breath in and instead of focusing on going faster, as is so often the case in the modern world, tried to slow things down.

Slowing down the speed of light is something that has been floating around the scientific community for years. In fact, just travelling through the non-vacuum of the world can slow down some photons, but the average speed of the wave is not affected. Traditionally, if a photon slows down due to a barrier such as glass or water, it will speed back up to about 186,282 miles per second and make up any lost time. This is due to the wave-particle duality of photons, meaning that the individual particle speed matters

less than the overall average travelling speed of the wave as a whole. However, is it possible to slow down an isolated individual? Well, as Dr. Daniel Giovanni, a head researcher from Glasgow, expressed, "It's just one of those big, fundamental questions you may want to ask yourself at some point in the pub one night."

How the Scotland team managed to slow down an individual photon was by forcing it through a mask of sorts: a barrier that changed the shape of the photon. By significantly changing the shape of an individual photon, the researchers were able to permanently slow it down to below the quantified speed of light - as opposed to travelling through glass or water, which only affects the photons temporarily. The affected photon was then sent down a specially made racetrack inside a vacuum, where it met up with one unaffected photon. The two photons "raced" down this track, and were recorded passing a defined finish line.

In this experiment, the affected photon finished on average about a millionth of a meter behind the unaffected photon, or around 20 wavelengths. A millionth of meter may not sound like that much, but when you are dealing with a particle that is technically sizeless because it is so small, this is a pretty significant difference.

While as of yet, there is no practical use for this advancement, it is theoretically interesting. This is evidential proof that maybe the speed of light is not the constant we all thought it was - it seems it may just be more like the upper limit on how fast something can go. If nothing else, this experiment shows that there is much more to learn about the nature of light and photons. ■

Science (2015). DOI: 10.1126/science.aaa3035.

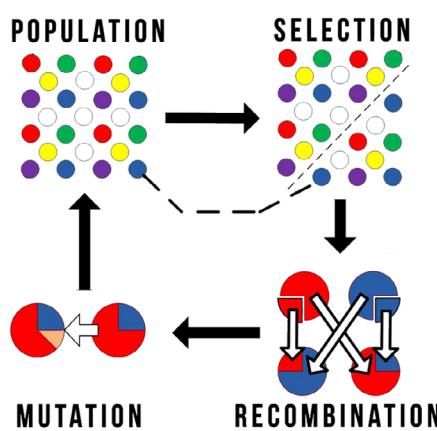
GENETIC ALGORITHMS

BY ALEX CODA, PHYSICS AND MATH, 2017

When it comes to creating the world of the future, it doesn't always take brilliant insight or tremendous efforts to make something great. Genetic algorithms are a technique that employs the principles of natural selection to take the heavy lifting out of complicated engineering and design. Given some problem, rather than going the usual route of sitting down and trying to reason it out, a genetic algorithm will treat many possible solutions like a population of living beings. These solutions will be bred with each other and mutated along the way, with the best solutions of each generation being selected to pass on their genes.

NASA scientists employed this approach back in 2003 to develop antennae for spacecraft. What they came up with looks totally wonky and unlike anything that is well engineered, but this crazy shape was found to be optimal for radio transmissions. And rather than being ingeniously designed, it was just happened upon by a computer program, randomizing the bends and lengths of wires and testing them along the way to select out better and better antennae.

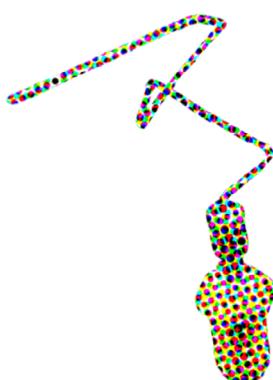
The applications of this simple yet powerful tool reach well beyond spacecraft. Fundamentally, genetic algorithms are just one of many ways of solving optimization problems. They have been used in as



diverse fields as robotics and finance, to find solutions that are as clever and perplexing as NASA's antenna. Despite its diverse uses, it should be noted that genetic algorithms are not always the best approach. In sufficiently complex problems, the randomness involved in genetic algorithms slows things down too much. Evolving an antenna might be okay, but try evolving a whole spacecraft and you'll probably be waiting at the computer for the next few millennia (just look how long it took for some of life's innovations to spring up). Similarly, if you don't have a clear idea of what you're trying to engineer, it's nearly impossible to determine which members in the population are fittest and should seed the next generation.

As long as one bears in mind when to employ genetic algorithms, they can be extremely versatile. Using only a bit of programming and some basic lessons from biology, a champion can be coaxed up out of the evolutionary mire of ones and zeroes to build the world of tomorrow. ■

University Computing (1993).
David Beasley et. al.



New Discoveries From the Same Old Drugs

BY CICELY KREBILL, BIOCHEMISTRY, 2019

Every year, countless amounts of time, resources, and money are spent on drug development. Unfortunately, the failure rate of these projects exceeds 95 percent. The headway made in the research is often halted due to a lack of funding or the inability to modify a molecule to behave in a way in which the researchers need it to. This high failure rate means that historically there have been many partially developed molecules in existence that could be potential solutions to diseases, if only they could get a little more attention. However, an area of research that is becoming more popular serves to remedy this problem: drug repurposing and drug rescuing.



Drug rescuing involves further studying any information discovered throughout the drug development process, and drug repurposing reexamines drugs that have been FDA approved to see if they could be used again to combat other conditions or diseases that they were not originally created for. Although their processes are slightly different, both are frequently referred to as drug repurposing in the drug development world and they essentially achieve the same benefits. They save both time and money when trying to create new, safe drugs to put out into the market.



On average it takes from 13 to 15 years and at least one billion dollars in funding to develop a drug from when the research starts to the final FDA approval. Unlike this traditional drug development route, drug repurposing begins screening multiple developed drugs or molecules against

a specific disease to see what is most successful and continue the research from there. This drastically shortens the time in which a drug becomes available for use on market. When a drug is repurposed, it takes as little as five years to get the drug approved and ready to distribute to patients. "What you're doing is taking a lot of risk out of the drug discovery process when you start with compounds much further along," says Dr. Michael Pollastri, a Northeastern Professor who uses the repurposing approach to find new compounds to combat neglected tropical diseases. This is because the compounds tested are frequently ones that have been proved to be safe in humans, meaning many of the reasons a drug would initially fail have already been cleared. It's also cheaper, Pollastri says, "Sometimes the side effect [of a drug] can be as useful or even more profitable than the original indication was."

"ON AVERAGE IT TAKES FROM 13 TO 15 YEARS AND AT LEAST ONE BILLION DOLLARS IN FUNDING TO DEVELOP A DRUG."

The importance of drug repurposing has recently become a more recognized and funded method of research. The National Center for Advancing Translational Sciences (NCATS), which is under the National Institutes of Health's (NIH), recently launched a program to encourage researchers to pursue repurposing. This program, which is known as either the Discovering New Therapeutic Uses for Existing Molecules Program or the New Therapeutic Uses Program, was started as a pilot initiative in May 2012. Its goal was to create partnerships between academic researchers and pharmaceutical companies that would give researchers access to information on many previously developed molecules. It encourages these partnerships by creating a template agreement that is used to facilitate the creation of intellectual property contracts.

Dr. Christine Colvis, Director of Drug Development Partnership Programs at NIH, believes that "a key feature of this program is the involvement of multiple pharmaceutical companies and the potential for any U.S. researcher to participate." This model, in which academics are given a limited amount of confidential information about drugs, hasn't been used all that frequently. Colvis thinks that this method has the potential to be used for partnerships between government, biomedical research organizations and industry.



Pfizer, AstraZeneca, and Eli Lilly and Company were some of the first pharmaceutical companies to join. Since then, many others have seen the success of this new method and have wanted to get involved. These companies provide a list of compounds and their known information to a large community of researchers, who in turn submit applications of what molecules they want to study related to a specified disease or condition. This approach has started to shift the focus of drug development research because the academic researchers propose what they want to study as opposed to allowing the pharmaceutical company to decide. Pollastri thinks that this shift "has been really beneficial to the rare disease world where there are small patient populations that drug companies wouldn't invest a lot of money in."



Although in 2013 only nine groups were funded through NIH, the information provided by NCATS to encourage drug rescuing

and repurposing helped other researchers make important strides in the creation of new drugs. In November of 2014, a new paper was published in which a group of researchers found 53 compounds that could potentially block Ebola. This was found by testing 600 FDA approved drugs, as well as 2,216 drugs provided by NCATS.

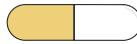
Access to previously researched molecules changes the face of drug research. Because of the information provided, researchers are able to test the potency of a variety of different compounds to continue research, greatly increasing the likelihood for success.

Often, the solutions to the diseases are found in molecules that were developed for vastly different purposes. For example, in the Ebola study, the most potent compound

found was one previously developed as an anticancer drug. Active compounds in antidepressant, anti-inflammatory, and female infertility drugs also proved to inhibit the Ebola-like strain. It is unlikely that these drugs would've been researched in tandem with Ebola without the access to the molecule collections like those provided by NCATS.

to be seen, but from what has been done with them so far, the field certainly seems to hold a lot of promise. These research methods and the new era of information sharing truly show the new innovation on the horizon for drug development. ■

Emerging Microbes and Infections (2014). DOI: 10.1038/emi.2014.88.



Whether or not drug repurposing and drug rescuing will supersede the more traditional route of drug development is yet

LARGE STRIDES IN CURING DIABETES

BY JOSHUA COLLS, BIOLOGY, 2017

Type 1 diabetes, which is highly prevalent in juveniles, subsists as an intra-pancreatic deficiency of insulin secretion. Systematically governed by the pancreas, healthy beta cells produce insulin to facilitate glucose uptake from the blood into cells. The insulin target receptors bind insulin, signaling for glucose import proteins (GLUT) to rise towards the surface and uptake a needed amount of glucose from the blood. This symbiotic process helps maintain a homeostatic blood glucose level, and gives cells the energy needed to perform necessary intracellular tasks.

However, in Type 1 diabetes, an irrational autoimmune response destroys beta cells, and inflames pancreatic islets required for regulating glucose. The resulting hyperglycemia is traditionally treated with insulin injection therapy to augment glucose uptake. While treating the effects addresses the symptoms, the underlying cause of beta cell dysfunction still remains at large.

Researchers at Harvard Medical School and Brigham and Women's Hospital have been experimenting with mesenchymal stem cells (MSC) to utilize their known anti-inflammatory and immune suppressing characteristics. It had been previously observed that intravenous MSC given

to diabetic mice only temporarily improved blood sugar.

Scientists decided to feverishly target the islets of the pancreas that encompass the beta cells. By employing a ligand (HCELL) that seeks inflamed tissue, the entry of MSC to the pancreatic cells is greatly facilitated and widely effective. The stem cells were found to have a profound and sustained effect on blood sugar levels by helping to promote beta cell function.

Using this initial experiment as a basis, the prospective application for medical usage no longer seems daunting. The potential for a similar treatment being used for human diabetes mellitus appears conceivable and on the brink of a new horizon for curative discoveries. ■

Endocrinology (2014). DOI: 10.1210/en.2014-1677.



Hayward Thinking

BY KAYLA GOMES, PHYSICAL THERAPY, 2017

Collaboration spurs innovation. This spring break, Dr. Lorna Hayward and 15 physical therapy students will be traveling to work in orphanages in Ecuador. Among the 16 50-pound duffel bags filled with their supplies are three laser-printed iPad covers and 3D-printed touch screen guards designed by engineering majors in Northeastern's Enabling Engineering (EE) club. These will be used by children with cerebral palsy, a neurological disorder that can affect body movements and communication. NU Sci spoke with Dr. Hayward and the heads of the iPad cover team, sophomores Samantha Bell and Marina Eaves, about this interdisciplinary project.

Hayward, an associate professor of physical therapy at Northeastern, has been bringing fifth-year doctoral physical therapy students (DPTs) to Ecuador for the past eight years. Drawn by Ecuador's rich history of Evangelical missionaries trading medical supplies and religion to the indigenous people, Hayward was inspired to bring her students to perform work in physical therapy and to learn more about the needs of the community.

"It took about three years for us to have an understanding to what we could do for each other," said Hayward. "That's a big part of doing international work, understanding what the partner really needs."

The trip is a part of the PT Project, a two-semester capstone for physical therapy students. During the first semester the students conduct research on different diagnoses in order to come up with sustainable, targeted interventions, which they attempt to put in place during the 9-day Spring Break trip.

Working in two orphanages, Dr. Hayward and her team see children in a setting with a unique set of challenges.

"We're working with abandoned, orphaned children, and typically the kids have parents that are really poor or there are issues with substance abuse, so that's why a lot of the kids have issues that need to

be addressed," Hayward said. "There are different challenges," one of which is the concern that the targeted interventions the team puts in place may not be carried over.

The group is bringing in iPads that have specific apps to facilitate communication for the children with cerebral palsy. The tias, or the children's caretakers, have a tendency to take the iPads away, so Hayward and her team are working on a solution.

We're fabricating with a laser printer a large otterbox and have these 3D printed touch screen guards," Hayward explained. "The key guards actually allow the kid to be targeted where to touch the screen to show things that they want. So we're customizing these devices so they don't get put away."

A team of engineering majors from Northeastern's Enabling Engineering (EE) club created these customizing devices. The EE club uses engineering technologies to build low-cost devices that improve the lives of the elderly and individuals with cognitive or physical disabilities. Their goal is to give these individuals greater independence, reduce medical errors, and increase social connectedness, all at minimal cost. According to Marina Eaves, a mechanical engineering major, and Samantha Bell, mechanical engineering and physics major, the Otterbox apparatus and touch screen guard were originally created for students with various cognitive and physical disabilities at the South Shore Education Center.

"The students live with physical and/or cognitive disabilities, and communicate largely through iPad applications that show a set of buttons that students can press to ask for different things or create sentences," the two sophomores explained. "The issue, however, was that some children couldn't point accurately enough to ask for what they needed. The teachers suggested some sort of plexiglass cover with holes over the buttons, and the group took that idea and grew it into what it is today."

Whether the technology is being used for children on the South Shore or in an orphanage in Ecuador, the main concern is durability. According to the EE representatives, the largest issue was keeping the system together without using a latch or button. To solve this, the aspiring engineers created a plexiglass cover that was a latch in itself: the device was held vertically by tracks and over bumpers that arrested horizontal motion.

Seeing the opportunity for collaboration and lower cost solutions in Ecuador, the EE club advisor Waleed Meleis put the Otterbox touch screen guard team in touch with Hayward. Their products required a slight modification so they could be mounted on wheelchairs but otherwise the guards were, as Bell and Eaves put it, "ready to endure a lot of abuse."

"The biggest rush is what the students get out of it. It's fun to see them put their skills into play and gain confidence in their skills."

The touch screen guard is adaptable to any application, and the customized iPad devices are already in demand. The possibilities are endless, and Bell and Eaves are excited to see where their project can go.

"Our main interest would be in developing a manufacturing contact for larger scale production so that we might reach a larger user population and still have control over the price tag," Bell and Eaves said. "We want to keep the guard low cost and accessible to everyone."

So far, the engineers who designed these devices are not part of the team that travels to Ecuador, but Hayward mentioned that she would soon start applying for grants so that members of the EE club might join the DPT students in the future. For now, both groups recognize how valuable working with other disciplines was for this project.

"As engineers, Sam and I can create things like the touch screen guard and do pretty well, but it's the physical therapy students and Dr. Hayward who know how to take our designs and give us invaluable insight into what will really help these kids," Eaves said. "Collaborating with other departments provides us with multiple perspectives, which allows us to better anticipate problems with the design and to ultimately create the best and safest product possible."

Hayward agreed. "It's been so fun to work with other disciplines," she

said, adding that one of the key things she learned from the EE club is that when it comes to complex problems, sometimes the simplest solutions are the best. "The engineering students are so cool," she concluded.

Hayward also enjoys the growth her physical therapy students experience and the impact they leave on patients. "The biggest rush is what the students get out of it," she said. "It's fun to see them put their skills into play and gain confidence in their skills."

When asked what's in store for the project in the future, Hayward's response was enthusiastic. "We'll go and look for new challenges," she said. "Look with that eye for new challenges as a therapist with a clinician's hat on to look for new opportunities."

By continuing to apply the interdisciplinary approach her team used for the iPad touch screen guards, Hayward and her team are sure to find a new solution. ■

OVERCOMING ADVERSITY: THE ROLE OF BRAIN PLASTICITY

BY ALEXIS STEFANO, BEHAVIORAL NEUROSCIENCE, 2017

Studying the effects of child neglect and abuse is tricky, as scientists have ethical obligations to the safety and wellbeing of their subjects. However, when unfortunate humanitarian situations arise, case studies can allow researchers to learn more about the negative effects of early adversity. Ultimately, scientists hope to find out how to better the lives of children who have had difficult experiences.

In 1989, the collapse of the Romanian Ceaușescu regime resulted in many unwanted children being sent to government-run orphanages with poor conditions and childcare. Infants rarely received vital one-on-one interactions, and there was an extremely high child to caretaker ratio (sometimes 17:1). In a study released in January 2015, researchers in Romania and the US studied children who had been placed in high quality foster care as an alternative to the neglectful orphanages as part of a clinical study. Through a brain scanning technique known as diffusion tensor imaging, the scientists examined the children's volumes of white matter, the parts of the brain that contain axons where information is sent between neurons. The axons are coated with a substance called myelin,

which helps them to send messages faster and makes them appear white on a brain scan. The researchers wanted to know if the early intervention foster care had improved the development of the children, and if so, how. What they found was encouraging.

Quantity of white matter in brain areas critical for emotional and cognitive development was compared across three groups of children: 26 children who remained in the orphanages, 23 children who were randomly assigned to foster care, and 20 children who had never experienced institutional care (these children were matched with foster children in terms of social and demographic groups to ensure that these were not adding another source of variability). They discovered that the children who had remained in orphanages had significantly less white matter in their brains than the other two groups. The brain areas showing reduced white matter in the institutionalized children, such as the corpus callosum and corona radiata, are highly involved with cognitive, emotional, and behavioral development.

The corpus callosum is also responsible for communications between the two brain hemispheres and abnormalities

in this area have been linked to ADHD and cognitive and language delays.

Meanwhile, the foster care group had slightly less white matter than the never-institutionalized group in certain brain areas. This implies that there is a "potential for remediation," meaning that early intervention could actually repair a child's brain and put them on track for normal development.

Although similar studies have been conducted in this area, the children tested had been internationally adopted and therefore chosen by their families. This was an easily accessible pool of test subjects, but created bias because the children that moved to family care were not randomly assigned as they were in the recently released study.

Despite the advantages of this study, there is still much to learn. Scientists want to know if there is a critical period for early intervention foster care, or if ongoing exposure to better care throughout childhood would sufficiently improve white matter development. ■

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