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NU SCI

REVOLUTION

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LETTER FROM THE EDITOR

Revolution comes in many forms. For scientists, it often refers to groundbreaking discoveries or new technologies. For writers, it consists of the illustration of new ideas that others haven't thought of yet. For politicians, it recognizes a dramatic change in government or ideals.

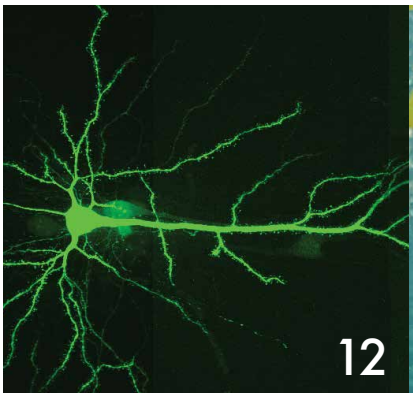
Regardless of the field in which it originates, revolution is about making something new. It indicates progress. It's necessary and also exciting. As The Beatles so eloquently put it, "we all want to change the world." This issue of NU Sci recognizes those who change the world by covering revolutions past, present, and future.

Read on to learn about how Galileo's experiments revolutionized the way we think about the planets, how aquaculture is impacting the fish farming industry, and how wearable technology is helping to create a non-invasive method for patients to participate in clinical trials. Whether you're interested in learning about the rise of autonomous vehicles or want to know where we stand regarding artificial intelligence, this issue has something for you.

We are undergoing tumultuous changes politically, and therefore are at a critical time when it comes to scientific progress. As Katie Hudson, NU Sci president, discusses in her article for this issue, we may be in the midst of a second Scientific Revolution. To better understand where we are headed, it's important to look back on past scientific revolutions as well as forward – to the future of climate science, to the medical uses of spider silk, and to the next crop of scientists who are destined to make an impact in an ever-changing world of scientific research.

That's what our team has done here. By picking up this magazine, you're counting yourself in to our own small part in the Scientific Revolution. Thanks for participating.

Gwendolyn Schanker
Editor-in-Chief



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This Semester in Science

BY SAGE WESENBERG, BIOCHEMISTRY AND JOURNALISM, 2019

DESIGN BY ANNIE LEE, DESIGN, 2019

Environment

On January 25th, the Long Island Power Authority (LIPA) approved a new offshore wind farm that will be built by 2022 between the tip of Long Island and Martha's Vineyard. This will be the largest wind farm in the nation, with 256 square miles of space that gives the ability for up to 200 turbines to be built. The LIPA was approved to start with 15 turbines off the coast of Montauk that can harvest enough energy to power 50,000 average homes. If all goes well with these beginning turbines, they will be the gateway to the rest of the project. Even though each turbine is about 600 feet tall, and only 35 miles off of the coast, their large structures should not be visible from the New York coast and once built near Massachusetts, should only be barely visible from Martha's Vineyard. This is the beginning of a rather long process: scientists will start to study and map out the ocean floor in this region to determine where and how each turbine will be securely anchored. Once planned out, the LIPA has to get both federal and state permits for construction, which should start by 2020, allowing for power to be transmitted by 2022. This approximately $740 million project holds great hope as an alternative energy source for many homes on the east coast

Politics

As of the end of January, in the first weeks of Donald Trump's presidency, the scientific world is seeing many changes and obstacles come their way. Climate change scientists are concerned about the future of the planet as Trump plans to move forward with an increase in fossil fuel productions in order to create more jobs. Additionally, he has been putting holds on data sharing, research grants and contracts for many scientific topics, especially climate change. While he has not said outright that he denies climate change, with minimal information about climate change plans on his website, and his only plan for the energy policy being fossil fuels, scientists are fearing a reverse in the progress made in the past years. Information about the EPA is also under scrutiny and although nothing has explicitly been finalized yet, scientists are also concerned about NIH funding cuts, which would have drastic impacts for federal research across the country. With Trump and many of his top officials voicing their opinions against many forms of valid science and research, scientists across the nation are in fear of what the next months of the presidency will have in store.

Food

Who would have thought the classic tomato could make headlines? The University of Florida published research in Science to determine why the supermarket tomato is lacking in flavor, and how to fix this problem through genetics. By using classical genetics, they looked for which chemicals in a tomato are most important for taste. In the last 50 years, many tomatoes have lost good flavor because breeders didn't have a tool to screen for flavor, created by sufficient sugars and some volatile chemicals. Scientists were able to identify the locations of good alleles in the tomato gene that give the specific traits, and then gene mapped the ones that control the production of important flavor chemicals. Finally, through genetic analysis, they replaced bad alleles in the modern tomato with better ones that are able to synthesize the chemicals needed to make the tomato taste better. But don't get too excited yet. It will likely take up to four years to produce new varieties of tomatoes that contain these alleles to help them explode with their deliciously sweet flavor.

Psychology

A research team from the Zurich University Hospital for Psychiatry recently published their findings on the effects of LSD on perception of meaning, as a way to find and trace different meaningfulness neurochemicals and receptors in our brain. Through understanding of the human experience, an abstract research topic, the researchers hope that they can attempt to use more targeted drug treatments in treating different psychiatric illnesses. LSD is a psychedelic drug that alters the meaning and relevance to one's environment and changes how the users see themselves. It has always been difficult to comprehend what part of the brain controls this. The first part of the research looked to confirm that the usual effects of LSD were seen as they modify consciousness, mood and anxiety. By using this information, brain imaging, and behavioral assessments, researchers were able to correlate the processing parts of the brain with the personal meaning and relevance. They determined that personal meaning and the effects from LSD are controlled by the 5-HT2A receptor and the cortical midline structures that are necessary for neural self-definition. These results may help us more concretely understand how we perceive our sense of self. Future research will look at how their findings correlate or change in patients with psychological disorders.

Health

Recently, a team of biologists from the Salk Institute for Biological Studies of San Diego, CA successfully grew human stem cells in a pig embryo. This research provides great hope for the process, which generates stem cells directly from a patient's skin and then transfers it to the animal, likely a pig, where the organ can then grow before harvested to be put back into the patient. An animal composed of two genomes, like in this case, is called a chimera. Because the organ is grown from the patient's own cells, there is a much lower risk of infection, compared to other transplants. Another study from the University of Tokyo and Stanford studied the ability to reverse mice diabetes by growing mice pancreas glands in rats and transplanting them back into mice. With these successful results of chimeras in mice and pig embryos, researchers plan to repeat their experiment in full-grown pigs, since now there is potential for a larger scale to grow human organs.

YOU WANT A (SCIENTIFIC) REVOLUTION? I WANT A (SCIENTIFIC) REVELATION!

BY KATIE HUDSON, MARINE BIOLOGY, 2017

DESIGN BY ANNIE LEE, DESIGN, 2019

The Scientific Revolution, as it is traditionally defined, occurred between 1500 and 1770. During this time, the scientific method that we rely on today took form. Famous scientists developed the laws of motion and gravity, discovered how the human body and its systems work, and created the first microscope. This era in history, without a doubt, laid the groundwork for the current body of science we have today. During this time, the way individuals thought about science changed significantly and, because of this, the scientific community was able to take monumental steps towards developing the science we study and know today.

One of the most influential scientists of the Scientific Revolution was Galileo Galilei. Galilei lived before Newton, from 1564 to 1642. As an astronomer and mathematician, Galilei is best known for his work in astronomy. Galilei was the first to develop the modern telescope and observed many of the planets in our solar system. He also developed the theory of a lunar-driven tidal cycle. As a result of these stellar observations, Galilei was a strong advocate for and improved upon theories arguing for a heliocentric, or sun-centered, solar system, originally theorized by Nicolaus Copernicus in the early 16th century. Galilei was such a strong advocate for this idea, however, that he was eventually prosecuted by the Church and forced to denounce all of his work on the subject. Galilei was eventually forgiven by the Church after his death.

In addition to his work in astronomy, Galilei was also an extremely influential mathematician, developing the initial theories on circular motion and inertia and the physics behind falling objects with his famous theoretical experiment of dropping a light and heavy object from the top of the Leaning Tower of Pisa. As a result of these theoretical experiments, Galilei was one of the first scientists to conduct repeated experiments. This led Galilei to develop the modern scientific method as we know it today, paving the way for modern scientists worldwide.

Sir Isaac Newton was another extremely influential scientist during the Scientific Revolution. Newton lived from 1643 to 1727, in the height of the Scientific Revolution. Building off of the works of Galilei, Newton's work formed the foundation of modern physics, working in both optics and mechanical physics. Newton developed the field of modern optical physics with his discovery that white light is made up of multiple colors or wavelengths of light. This discovery was monumental for modern medicine and eventually allowed for the development of x-ray and MRI technologies. In addition, most present-day imaging technologies, such as sonar and thermal imaging, are based in optical physics.

Newton is most famous for his work in mechanical physics and mathematics. Newton developed three laws of motion that have since formed the basis of modern physics. These laws of motion detail the conservation of energy, inertia, and momentum. In addition to these laws of motion, Newton developed the theory of gravity and the gravitational constant used in modern physics. These laws have been critical to the development of several fields of science and the development of modern technologies such as cars and space shuttles.

Anyone who has taken a college-level calculus course can thank Newton for a wonderful semester. Newton developed the mathematical theory of calculus. Calculus has played a role in modern physics as much as the laws of motion. Without calculus and other advanced mathematics that are derived from calculus, space travel and exploration would be impossible.

Although the original Scientific Revolution occurred over 300 years ago, in light of the new technologies that have been developed since the late 20th centuries, some historians have argued that we are in the midst of a second Scientific Revolution. This second revolution may even be similar to its predecessor socially as well as technologically. As technology moves forward at an unprecedented rate, it is allowing scientists and the general public to think about and view the world around them in a variety of different ways. With this mindset, individuals continue to take monumental steps to move science forward. Only time, however, will tell if this movement will be as monumental as its predecessor.

ELECTRIC CARS: ARE WE THERE YET?

BY RAFI RAZZAQUE, ENVIRONMENTAL SCIENCE, 2019

DESIGN BY ANNIE LEE, DESIGN, 2019

Before the car, there was the electric car. Thomas Parker's 1884 electric car predated the invention of the modern automobile by a year. However, a lack of infrastructure and limited battery developments prevented them from being useable and widespread, relegating electric cars to expensive estate pieces for the rich. Although almost a century late to the party, electric cars are finally making a mainstream impact again, with companies like Tesla becoming household names.

While electric cars have become more popular, mainstream car manufacturers have struggled to meet rising fuel economy standards. Many manufacturers have shifted development and production towards using electric motors to supplement or replace conventional internal combustion engine (ICE) cars to meet stringent fuel economy and emission standards. Because they reduce greenhouse gas emissions and are eligible for federal and state tax cuts, electric cars have potential to curve our relentless thirst on fossil fuels with cheaply available electricity.

> "Although almost a century late to the party, electric cars are finally making a mainstream impact again, with companies like Tesla becoming household names..."

With electric car mileage ranges improving due to technological and developmental improvements, these cars are more and more viable as replacements for conventional ICE cars. Car manufacturers are pledging to or hinting at replacing their current lineups with plug-in electric cars, creating sharp competition in the electric car market. Elon Musk, CEO of Tesla, has released open patents of his electric technology for other manufacturers to take advantage of to help usher in the new era of automobiles.

So where are all the electric cars? President Barack Obama, in his 2011 State of the Union Address, challenged the US to have a million electric cars on the road by 2015, yet it took until August 2016 to meet him halfway. In 2016, electric cars made up less than 1 percent of new car sales—154,000 out of 17.55 million—not helped by the fact that gas prices were under $2.35/gallon in 2016 compared to $3.35/gallon in 2011.

This may be because consumers are currently wary or unwilling to buy electric cars. In a 2016 EPA study, 56 percent of a surveyed group needed a car that could handle 300 miles of usage (range) on a single charge. The only cars capable of actually handling 300 miles of range are the range topping Tesla Model S and X cars, costing well over $90,000. The EPA survey also noted that 55 percent of the surveyed group believed electric cars today were 'too expensive.'

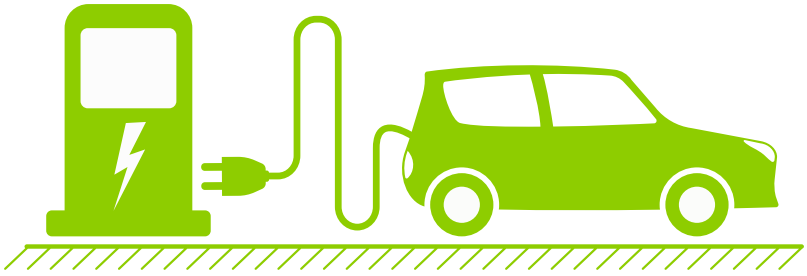
Although Tesla and Chevrolet are committed to releasing cars in the $35,000 bracket - on par with the average price of new cars in 2016 - with over 250 miles of range, there are other questions to be answered before electric cars become the norm on the road. For one, electric car infrastructure will take a while to implement; there are 15,000 charging stations and 39,000 charging outlets in the United States, compared to 115,000 gas stations. Charging an electric vehicle also takes time, with some vehicles requiring as long as a workday to recharge fully.

One of the biggest failings of electric cars can be chalked up to their batteries. Electric cars utilize lithium-ion batteries not much different from those used in a phone or a computer; the Tesla Model S makes use of 7,104 cylindrical batteries the size of a phone charger wired together to run the car. These batteries are not just expensive, accounting for 21% of the total cost of the car, they are also not the most ecologically friendly choice for a car set on reducing its environmental footprint.

Replacing lithium-ion technologies has proven problematic, with scale, cost and production limitations preventing solutions and replacements from taking hold. Increased research and development may pay off with better mileage and more ecologically friendly production methods, but production costs are still prohibitively expensive. For now, electric car manufacturers will struggle to push the inherent boundaries of current battery technology.

So electric cars aren't quite there yet. Customers aren't ready to trust or afford them, and battery technology limits their affordability and range. However, willing competition between manufacturers and electricity suppliers to cater to a new generation of car buyers will up the competition in the field. In the meanwhile, we have a solution to curbing our fossil fuel thirst and reducing harmful pollutants.

So who wins? We, the consumer, of course! Cheaper electric cars with better performance and smarter technology just might be soon to come.



How autonomous vehicles are driving us to think differently

BY ERICA YEE, COMBINED INFORMATION SCIENCE & JOURNALISM, 2020

DESIGN BY ANNIE LEE, DESIGN, 2019

If you head a few miles east from Northeastern's campus, you might see a small white car with someone in the driver's seat but no hands on the wheel. Don't freak out! The first autonomous cars have just landed in Boston.

NuTonomy launched the first self-driving car here in January. The Cambridge startup has an agreement with the city to gradually "graduate" its cars from roaming industrial parks to traveling the surrounding neighborhoods, always supervised behind the wheel. Boston's crowded streets and often poor weather conditions pose challenges and learning opportunities nuTonomy's cars have not faced in their previous testing location: the clean, peaceful Singapore.

As the automotive companies race to get safer vehicles on the road, we can look at three areas where autonomous cars are revolutionizing transportation.

1. The rise of smaller, nontraditional players

How did nuTonomy, an MIT spin-off founded in 2013, develop cars capable of driving themselves on the road before long-established automotive companies?

"A lot of newer ventures have commercialized the technologies that can help run these types of systems. It's not the trend of suppliers historically," noted Tucker Marion, a professor of technological entrepreneurship at Northeastern University.

In the past, large automotive companies only bought components from other large automotive suppliers. Car manufacturers were conservative in the technology they used, prioritizing conventional hardware over innovative replacements. The vehicles must survive for years and in all types of weather, so the technology had to be very robust. Marion said, "You could make a general claim that the automotive industry used electronics 10 years behind consumer electronics."

Now, autonomous vehicles are using newer, more experimental technology. American company NVIDIA, for example, originally became widely known for creating graphics cards for playing video games. NVIDIA recently entered the automotive industry because of the similar need for fast-processing computing chips in self-driving cars.

"The risk that needs to be mitigated is they need to make sure that anything you put into a vehicle is robust enough to withstand the environment," Marion added.

2. Trusting an unseen Uber driver

Driverless technology may be improving, but advances are only useful if people are willing to take advantage of them. John Basl, a professor of philosophy and an expert in ethics of emerging technologies at Northeastern, observed, "You're going to see that there's a group of people that are willing to give up that control. We're going to start to have data and a shift demographically of people willing to trust it."

Public trust in autonomic cars varies widely; Tesla drivers, for example, are early adopters of autonomous technology. Last May, one such owner was the victim in the first known fatal accident involving a self-driving vehicle, though eight months later, the the National Highway Traffic Safety Administration cleared Tesla's Autopilot system of any fault.

Researchers estimate that operators are at fault in 94 percent of crashes, and that driverless cars could reduce traffic fatalities by up to 90 percent in a few decades. But it's hard for people to trust something they're used to controlling, even if driverless cars are statistically safer.

Basl added his own experience: "The next time a major accident happens, people will shy away. I've been in a Tesla, and I've had it veer the wrong way and scare me. It took me a little bit to readjust and trust the system again."

Media coverage can spin incidents in different ways as well. "There's an incentive to say the autopilot is at fault because that gets more clicks. Elon Musk is on record as saying something like 'bad press coverage of these things kills people.' But we have to balance people's legitimate fears about respecting autonomy," said Basl.

3. Regulating robots

Self-driving technology raises many questions not covered by existing laws governing vehicles. Should the vehicles be clearly marked? Do owners need a license? Massachusetts state legislators are already drawing up their own answers to those questions. Bill SD.1195 would require all self-driving cars under 8,500 pounds be zero-emission vehicles and would tax operators of those cars 2.5 cents per mile traveled, as zero-emission vehicles do not generate gasoline taxes.

"We don't know what the final form of the technology will be. It's hard to craft laws if you don't know what the technology looks like," said Basl. "But on the other hand, history has taught us that failing to look at these problems in advance can have certain costs.

Basl named Colorado's marijuana industry as an example in which the state initially set restrictive standards. Since legalization in 2012, the government has eventually done a live study, which has led to revisions because some anticipated problems did not come to fruition.

"It's better to go slow and be correctable than to go fast with risks we don't understand," Basl concluded.

As autonomous cars hit the road around the country, they are revolutionizing not only how we travel, but also how we think about the vehicles that get us there.

BY JORDYN HANOVER, BEHAVIORAL NEUROSCIENCE, 2017

DESIGN BY ANNA LI, BEHAVIORAL NEUROSCIENCE, 2019

Contrary to popular belief, the smart wearable revolution may have begun over five decades ago! Some people consider items like the Sony Walkman, introduced in 1979, as the beginning of commonplace 'smart wearables.' Others look to the 1960 invention of the head mounted television display as the start of a revolution. However, with the invention of items like Apple Watches, Fitbits and the Samsung Gear VR (virtual reality), smart wearables have seamlessly integrated into everyday life. Lately, pharmaceutical companies are looking to take advantage of the functions and capabilities of these wearables, utilizing smart wearables in their clinical trials to consistently and reliably monitor patients.

A 2003 report from the European Commission noted the ideal wearable smart system would integrate continuous monitoring via multiple sensors, intelligent processing, and health alarms to alert professionals in an emergency. Additionally, the device should be reasonably priced, lightweight, continuously connected to the desired online database, and be able to hold a charge. It is important to note that smart wearables differ from smart devices; a smartphone application where patients input data is a patient-reported outcome and differs from a smart wearable device that tracks blood pressure, for example. The report voiced concerns over the development of medical decision algorithms to help patients determine when they should seek in-person care, as well as how to confirm the reliability and validity of the data using such a technology.

One of the key components of using smart wearables is ensuring that the devices produce truthful and accurate data: regulatory bodies have specific guides for the use of computer systems in clinical trials, and require storage of all data collected. However, it has not yet been determined how incorporating these devices into clinical trials can be validated.

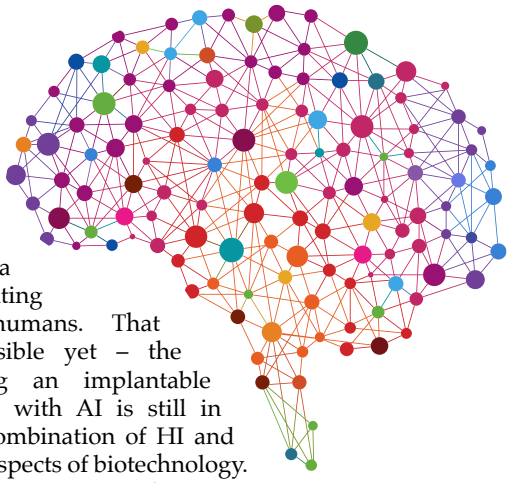
In 2014, a group out of the Good Automated Manufacturing Practice Japan Forum, an organization that helps determine standard clinical practices, set out to develop a regulatory guideline for these "smart and/or wearable" items' integration into clinical trials. Focusing on trials using contract clinical research organizations who support the company running the trial (often referred to as CROs), the forum determined that it is the responsibility of the organization to determine the risk factors involved. In this instance, any software or data management specific to the device would also fall under CRO purview. If there is no CRO, then it falls to the company conducting the trial to validate these devices. Additionally, the forum concluded that it was possible to develop guidelines to validate the devices, but there was nothing yet in place for the computer systems that would manage the electronic data these devices collect.

Some trials are already using these devices; there are over 100 trials globally that use a Fitbit to monitor activity or sleep or in combination with other devices. Other companies, like Google, are working on developing new technologies specifically for clinical trials. Announced almost two years ago, the Google life sciences team is working to develop a "wearable health sensor" that will monitor diagnostic measures like pulse and skin temperature. However, like the Japan Forum, the Google team also noted that developing the software to safely store and analyze the data is just as important as the device itself, and a unique challenge.

While many devices are untested in the clinical trial arena, it is clear that the innovation and development surrounding these test platforms provide a way for patients to participate consistently and non-invasively in trials. It is also possible that future smart wearables will allow patients to track their own progress in a trial based on the software collecting the data and trial protocol. There are also options beyond wrist watch-style devices in addition to wearable sensors. For example, Google has developed a contact lens with an embedded chip that can sense glucose levels in diabetic patients for a trial with Novartis. Despite the current hurdles to the integration of smart wearables into clinical trials, research and development groups clearly recognize the potential benefit that these devices could deliver patients through clinical trials and beyond.

Neuroprosthetics: Augmenting HI with AI

BY WHITNEY KUWAMOTO, BEHAVIORAL NEUROSCIENCE, 2020



Human intelligence (HI)—the curer of diseases, founder of sciences, and pioneer of interplanetary travel—has been outperformed by its own creation, artificial intelligence (AI). In the past decade, AI has already surpassed HI by completing simple tasks with greater accuracy, and will inevitably become more impressive in upcoming years. This raises one pressing question: how will HI compete with AI?

Brian Johnson, CEO and founder of Kernel, a startup that aims to improve human intelligence, believes that HI and AI will need to coexist with one another. In the future, humans will need to combine their intelligence with AI to achieve scientific breakthroughs that humanity currently only dreams of.

In order to do this, Johnson proposes the manufacture of brain implants based off of Dr. Tyler Berger's design of neuroprosthetics, silicon chips that replace damaged neurons by receiving electrical inputs from living neurons, processing them, then outputting an electric impulse to communicate with other neurons. Berger's research at UCLA focuses on duplicating neuronal wiring within the hippocampus, a structure responsible for memory recall.

Berger's neuroprosthetics have been tested in monkey and rat brains, but have never been implanted in human brains. At the end of 2015, Johnson contacted Berger proposing a joint project for implanting neuroprosthetics in humans. That project isn't fully feasible yet – the algorithm for creating an implantable chip that augments HI with AI is still in development, but the combination of HI and AI can be used in other aspects of biotechnology. The healthcare field, for instance, is planning to use neuroprosthetics as a way to increase the competency of patients afflicted with early stages of Alzheimer's Disease, a neurodegenerative disease that affects the hippocampus. Implanting silicon chips in Alzheimer's patients has the potential to alleviate debilitating symptoms like dementia.

While Kernel has adequate funding to support further research and manufacture of neuroprosthetics, there are still ethical hurdles that Johnson must overcome before these chips become a marketable product. Neuroprosthetics propose a technological revolution, opening the gate to higher order thinking facilitated by the use of AI. Individuals afflicted with cognitive deficiencies will be the first HI-AI super humans.

DESIGN BY ANNIE LEE, DESIGN, 2019

Sandra Shefelbine has got a she(l)f of knowlege

BY CHRISTINA WEBER, CELL AND MOLECULAR BIOLOGY, 2020

Sandra Shefelbine, associate professor in mechanical and industrial engineering at Northeastern, uses mechanobiology and engineering concepts to understand how the bone adapts to loads placed upon it.

In the Shefelbine Lab, she and her colleagues study multiscale mechanics and musculoskeletal mechanobiology, which means they study how stress on bones drives their adaptation.

One of Shefelbine's more recent accomplishments is her 2015 publication, "Predicting Cortical Bone Adaptation to Axial Loading in the Mouse Tibia," published in the Journal of the Royal Society Interface. "Bone is a dynamic tissue, responding to changes in mechanical demands by adapting its shape and material properties," the study states.

That publication included both mathematical models and biological information. Shefelbine mentioned how the "diversity of approaches is really interesting and exciting and potentially very powerful as well."

This experiment was conducted to counteract real life problems. One of the problems she mentions includes those who are paraplegic and are bedridden, which causes deterioration of the bone due to the lack of skeletal loading usually obtained from varying levels of physical activity.

She used a system to induce stress on bones called the axial tibial loading model. This is a non-invasive procedure where the external actuator contained two cups that were vertically aligned. The right tibia of each mouse was placed in between the cups. The left limb actually served as a control with no loading.

Ultimately, by building models with the use of engineering concepts and skills, she was able to map cortical thickness in the mouse tibia. She also found where, within the bone, the thickening actually happens.

Shefelbine credits much of her success to the environment of interdisciplinary collaboration at Northeastern.

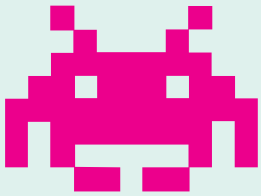
"The more you are exposed to, the more questions, opportunity and serendipity you have," she said.

Journal of the Royal Society Interface (2015). DOI: 10.1098/rsif.2015.0590.

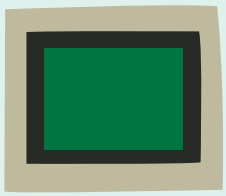
the DIGITAL

NU Sci takes a look at the inventions and ideas of the historical movement that set the precedent for technology of today.

1970s – – – – – – 1980s – – – – –



arcade games



home computers

motorola dynatac
first mobile phone

CD-ROM

THE RISE OF SOCIAL MEDIA – – –

Six Degrees
1997-2001

The first social media site, Six Degrees, was named after the "six degrees of separation" theory. Users could create and see each other's social circles.

Linkedin
2002 - now

LinkedIn was created for and is still used by professionals to network, find jobs and socialize. Originally, users could only upload their CVs for employers to view.

Myspace
2005-2009*

Before losing popularity to Facebook, MySpace was one of the first profile-based social media sites. Although still extant, most users are artists promoting their music.

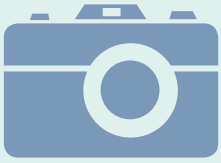
AIM
1997-2009

AOL Instant Messenger became popular in the late 1990s. AIM also popularized chat robots, which could receive and send messages based on their purposes.

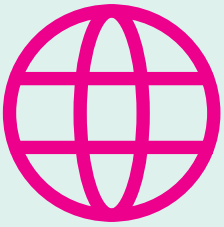
*Years show peak popularity; some platforms still exist with a far lower userbase.

REVOLUTION

1990s



digital cameras



world wide web

dial up internet

Facebook
2009 - now

Facebook is currently the top social media site, with more than one billion users. Recently, it has been criticized for its privacy policies — or lack thereof.

Instagram
2010 - now

Instagram is the most popular photo and video sharing application. It has popularized neologisms like “instafamous” — in reference to someone with a large following.

Twitter
2006 - now

Twitter allows its users to express themselves in 140 characters or fewer. It popularized the hashtag, and most recently has been a platform for legislation.

Snapchat
2012 - now

Snapchat skyrocketed in popularity as a platform for self-deleting images. The iconic Snapchat “ghost” was designed after Ghostface Killah of the Wu-Tang Clan.

Picture This: A New Future for Biological Imaging

BY UDBHAV CHITTA, BIOLOGY AND MATHEMATICS, 2019 DESIGN BY ANNA LI, BEHAVIORAL NEUROSCIENCE, 2019

On a daily basis, scientists of all wavelengths use imaging to present their findings in a visual way so more readers can understand the significance of their projects – whether that be revealing the double-helix structure of DNA or discovering a new species. Hundreds of thousands of peer-reviewed journal articles use some method of imaging to illustrate results, and a significant portion of these papers are dedicated to the process of imaging itself, from identifying fluorophores to developing new methods of imaging. Regardless of biological discipline - micro- or macro-biology - imaging is a vibrant, essential, and sometimes breathtaking part of any piece of scientific literature that captivates the readers' minds and brings the science to our eyes.

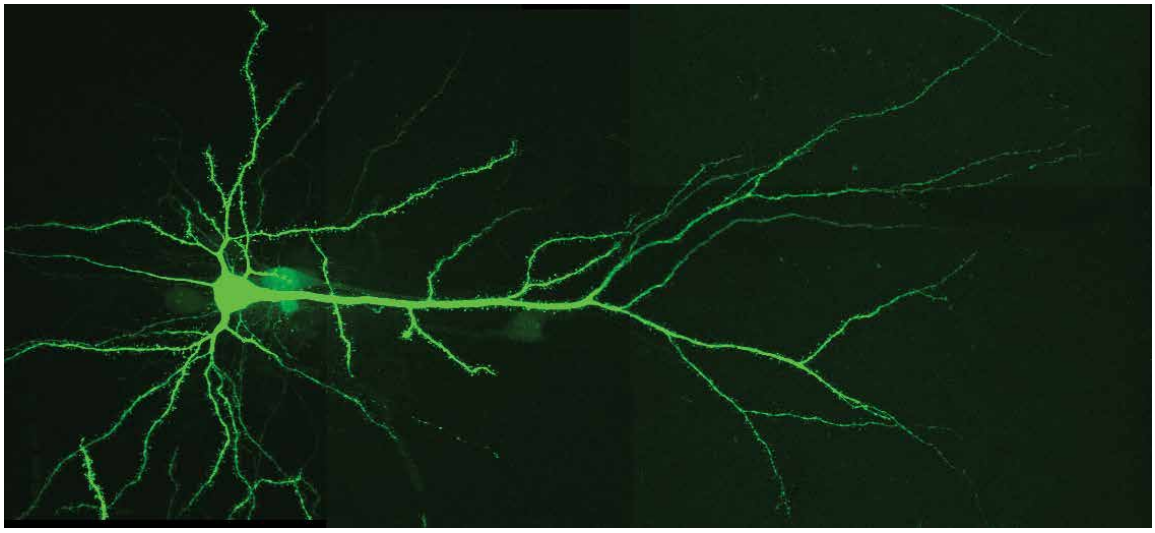


IMAGE COURTESY OF TINA GREUNE

Massachusetts Institute of Technology professor and synthetic neurobiologist Edward S. Boyden has revolutionized the field of imaging by debuting the imaging technique known as "Expansion Microscopy" in his recent Science publication. Professor Boyden works on researching the mechanisms of repair within the brain, aided by analytical and robotic tools.

According to Boyden, imaging is generally performed using refraction to magnify images of a specimen, which can only bring a scientist so far in terms of magnification. Expansion microscopy is the exact opposite, and works with the specimen itself, rather than the scope. By generating within a section of the hippocampus a polymer network that expands under experimental conditions, Boyden and his graduate students observed the expansion of the section itself. What was even more astounding was the fact that the tissue kept its integrity and form and was not anatomically compromised. By manufacturing a fluorescent label that is specific to this process, the method of expansion microscopy was tested multiple times. When researchers imaged organelles of the human kidney, they found that the images had sharper resolution than those taken with confocal microscopy, in which a pinhole aperture is used to eliminate any unfocused regions of light and thus creates a 3-D reconstruction of the section. Then the lab moved to the brain, the primary area of interest for Professor Boyden's lab and arguably the most complex organ in any organism's body. What resulted were sharp and detailed images of neurons, dendrites, synapses, and even a 3-dimensional rendering of the hippocampus. Suddenly the field of imaging opened up and this discovery ushered in a new era of science.

Now, the big question is: what can expansion microscopy be used for? Boyden already demonstrated that, in the brain, the super-resolution images can capture stunning images of complex neurological structures. One might consider applications relating to vital biochemical signals in the body or to the various molecular and cellular interactions. But the most promising field may be cancer biology: by using expansion microscopy, scientists may be able to better understand and visualize the signals responsible for metastasis, the process in which the cancer is no longer grounded to one area, which potentially results in the death of the patient. Using this newfound technique, the previously impossible imaging of molecular events is now seemingly in the grasp of researchers. This high-resolution method is one of the most significant examples of the vast usage of simple properties of polymers to observe the microcosm that is an organism's body. Ultimately, this discovery is just another example of the boundlessness of human ingenuity which can arise out of the simplest thoughts, and hopefully this is indicative of the future of imaging. Perhaps, in the future, we might capture the smallest biological and atomic movements.

Science (2015). DOI: 10.1126/science.1260088.

Building on the "Quiet Revolution" Empowering Today's Introverts

BY GWENDOLYN SCHANKER, JOURNALISM AND BIOLOGY, 2018

DESIGN BY KRISTI BUI, COMPUTER SCIENCE, 2020

January 24, 2017 marks five years since Susan Cain published her book, Quiet: The Power of Introverts in a World That Can't Stop Talking, breathing new life into the term "introvert." While introverts tend to hide their identity from an extrovert-dominated society, Cain argued, they have abilities all their own that allow them to make important contributions, whether in school or in the workplace.

"The secret to life is to put yourself in the right lighting," Cain wrote in Quiet. "For some, it's a Broadway spotlight; for others, a lamplit desk. Use your natural powers – of persistence, concentration, and insight – to do work you love and work that matters."

Cain's book not only recognized the power of introverts, it also helped shed light on a more multifaceted definition than is usually associated with the term "introvert." Analytical psychologist Carl Jung developed the archetypes of introversion and extroversion in the early 1900s. From Jung's perspective, introverts were more focused on the internal world, while extroverts were driven to involvement with others.

Today, introverts are often thought to be the opposite of extroverts, who are seen as more outgoing and generally more comfortable in social situations. This concept comes from Hans Eysenck, who in the late 1940s established the types as a single-factor continuum that described the degree to which a person was outgoing or gregarious. In the 1980s, the "Big Five" model of personality traits was created, a five factor-construct that established extroversion as one of the five basic domains of personality, with introversion as its opposite.

Though introverts are often considered to be simply "shy" or "anxious" around people, introversion can take many forms, at least according to Jennifer Odessa Grimes, a research assistant at Wellesley College who worked with her colleagues to develop a scale that identifies four types of introverts: social, anxious, thinking, and restrained. This spectrum of introversion is meant to steer away from the connotation that introversion is simply the opposite of the bubbly, more preferred extroversion.

"People are starting to realize that being introverted is not having a problem, it's just having a different way of being," Grimes says. "The changing expectation of what is normal, acceptable [and healthy is going to be very good for introverts."

That's especially true on college campuses, where a preference for quiet concentration can often be an asset – the number of hours most students spend in the library far outweighs those spent in class – but is viewed as a detriment when it comes to building a successful social life.

"I think college is a danger zone for introverts, because you're at the age when socializing is de rigueur," said Jonathan Rauch, a journalist and contributing editor for The Atlantic, whose 2003 essay, "Caring for Your Introvert," sparked a positive response from the introverted community. "It's an age when it's just assumed that you want to go to parties and you want to live in dorms and have people around you all the time."

> "People are starting to realize that being introverted is not having a problem, it's just having a different way of being."

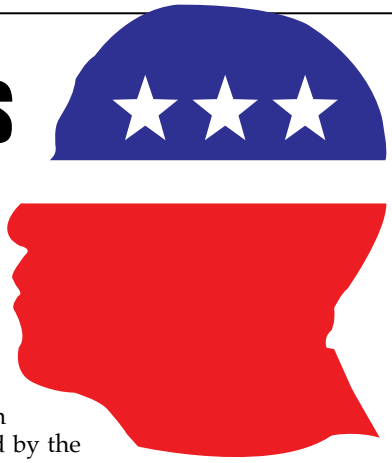
That lifestyle doesn't work for introverts, who, despite having an active social life, will lose energy from spending extended time around other people. Introverts need time alone to recharge, whether that takes the form of a cram session in the library or an hour of Netflix. As introversion becomes a more respected trait in today's society, today's college introverts hopefully feel freer to take control of their alone time, rather than adhering to strict social expectations or ideals.

In the past two years, Cain and her colleagues have built an online platform called the "Quiet Revolution," to encourage further disintegration of what Cain termed the "Extrovert Ideal." The site offers insight and advice for introverts and also allows for readers, termed "quiet revolutionaries," to submit stories about how introversion plays a role in their life, many of which are then published on the website. The team is also working to create a network of "Quiet Ambassadors" in the workplace, whose job is to foster connections of communities of both introverts and extroverts.

The growing presence of introverts in today's society, including on social media, doesn't mean there are more introverted people in the world than there were 50 years ago – introverts consistently make up one-third to one-half of the population. Instead it means that today's introverts are more comfortable speaking up, partly thanks to the work of Cain and other writers who have given voice to the power of introverts in the personal, academic, and professional worlds.

"I think the world is definitely very slowly awakening to the fact that introverts are here, and that there's nothing wrong with us, and we have nothing to apologize for," Rauch says. In fact, they have an important contribution to make: in a world of loud voices, it's essential to have plenty of good listeners.

REVIEWING PRESIDENT OBAMA'S ENVIRONMENTAL LEGACY



An op-ed on the former president's climate intiatives

As the curtain falls on Barack Obama's presidency, it is important to assess the changes he has brought to both our country and the world. In order to move forward, we must look back and learn from our predecessors. So, now that the Obama administration has officially departed, and its memory is fresh in our minds, let our review begin. Economists, political scientists, and sociologists can all argue over the impacts the president has had on the American society, economy and government. Today, however, we are here to talk about the environment, and the remarkable concern which our president has shown for it. For it is my opinion, as well as many others', that without a doubt President Obama will be remembered as one of the most environmentally progressive presidents in history.

To start with, Obama is the first US president to take global climate change off the back burner and move it to center stage. Under considerable opposition from the conservative, climate science denying sect of congress, and even some members of his own party, the president ultimately created a policy that started the United States on a path to achieve global energy independence and ease our use of fossil fuels. After the rejection of the Keystone XL pipeline in 2015, which would have spanned nearly 1,200 miles across six states, and moved more than 800,000 barrels of petroleum daily, the president stated in a press release "America is now a global leader when it comes to taking serious action to fight climate change. And frankly, approving this project would have undercut that global leadership." Moreover, in 2015 the president and the EPA introduced the Clean Power Plan, a program dedicated to reducing carbon pollution from power plants which would cut carbon emissions 32 percent from 2005 levels. In his most historic action on climate, the president ignored the consent of the senate, that would not have ratified the treaty, and signed the Paris Agreement himself, ensuring the United States was committed to progressive environmental solutions. The agreement was a landmark conference that aimed to significantly reduce global carbon emissions and curb today's rising temperatures to less than 3.6 degrees Fahrenheit.

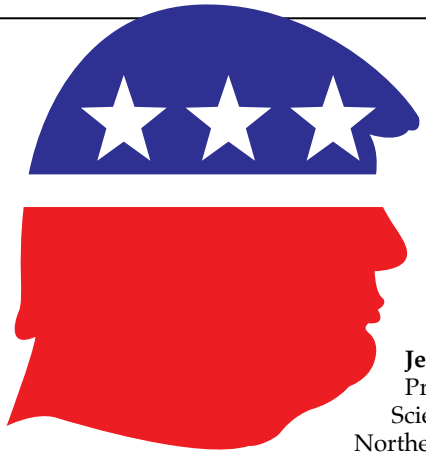
Mitigating climate change wasn't the only major way President Obama used his office to protect the earth. Obama granted formal protection to over 550 million acres of federal land, more than double the amount that President Theodore Roosevelt, the famous conservationist, protected. Obama achieved this feat by designating these areas as National Monuments, which are defined as cultural, historical or ecologically significant sites. He was able to place this protection through the use of the Antiquities Act, a law passed in 1906 that states that the president may grant special protection to "historic landmarks, historic and prehistoric structures, and other objects of historic or scientific interest that are situated upon the lands owned or controlled by the Government of the United States." Through his use of the act, Obama enraged many congressman across the aisle who accused the president of overstepping his authority. However, many times these legislators wanted to allocate the protected lands for resource harvesting such as mining, drilling and logging.

While it's these grandiose actions that have solidified Obama's legacy as an environmentally progressive president, some of his most critical works have been small actions that were overshadowed by larger issues at the time. For instance, not many have heard about the Microbead Free Waters Act, a bipartisan effort signed in December of 2015 that bans the manufacture and distribution of plastic microbeads in personal cleaning materials. These aquatic pollutants are known to absorb harmful chemicals and congregate within our fish and waterways, instead of being filtered out by wastewater treatment facilities. Additionally, in 2012 the Obama administration finalized a deal to raise fuel efficiency standards to 54.5 miles per gallon for cars and light duty trucks by 2025; a change that will drastically reduce our country's fossil fuel consumption by nearly doubling fuel efficiency of the average 2012 vehicle. Furthermore, in 2014 the president created the Federal Pollinator Health Task Force. This committee oversees a project to restore honeybee and other pollinator colonies, which have suffered in recent years, to sustainable levels by 2025. Examples of these small scale environmental initiatives can be seen across the administration's eight years in office, and are the type of no-brainer environmental initiatives that are beneficial to everyone.

Finally, as the new administration settles in, many environmentalists are cringing. Already, major environmental policies of President Obama have been under fire from President Trump, a man whose top priority is clearly not the health and wellbeing of our ecosystems. However, in President Trump's absence of strong environmental policy, President Obama's progressive thinking glistens. Never before have we seen a president so committed to advancing the health and wellbeing of the earth, while also committed to furthering the needs of our citizens in the process. Perhaps the first president to employ modern sustainable thinking on a large scale, he will be missed. So now, more than ever, it is crucial to remember: if it is the environment that we so care about, we must fight with our individual voice, our collective protest and ultimately our vote.

BY LUCAS PRINCIPE, ENVIRONMENTAL SCIENCE, 2019

BY ANNIE LEE, DESIGN, 2019



CLIMATE SCIENCE UNDER TRUMP

Words of cautious optimism from a Northeastern professor

Jennie Stephens, Dean's Professor of Sustainability Science and Policy at Northeastern's School of Public Policy and Urban Affairs, has spent her life learning about climate change, sustainability, and how society reacts to changing times.

"The situation we're in right now is very much linked to our inability to facilitate change and the very strong powerful interests that don't want there to be change," said Stephens.

NU Sci's Adanya Lustig sat down with Stephens to discuss her take on the new administration and coming trials in climate science.

What could change in the U.S. that would undo the progress we've made in addressing climate change?

It's difficult at this point to predict or project all the impacts of what the changes are going to be. Some decisions are being made quickly, but we don't know how those will play out, whether they'll be sustained or whether they're just in a temporary mode for a few weeks to figure things out.

There's a lot of concern about climate change being removed from all the websites. That in and of itself, in terms of the communicatory role and the agenda that the federal government has, in terms of a platform, is very noticeable. A lot of the scientists in the networks I'm in are concerned about this. They're more than concerned. It's like they're under siege.

There are so many possible ways for Trump to hurt efforts to combat climate change, whether it's dismantling the EPA, deregulating business, or signing off on Keystone XL. What is the scariest to you?

Expansion of fossil fuel extraction. We know fossil fuel extraction has all kinds of costs that are not integrated into what we pay on the market.

One thing I stay optimistic about is that the renewable energy transition and the momentum behind it is happening. People want renewable energy. It makes sense economically; it makes sense on so many levels.

Is there anything that's really safe that you're not worried about?

The reality is our fundamental environmental laws are actually very complicated and hard to change. There are executive orders that can be done quickly and have an impact. But the core of the whole host of environmental regulations: the Clean Water Act, the Clean Air Act. Those can't just be deleted.

There are a lot of government employees who are career scientists and administrators who have been working in these critical areas for decades and are not going to go home and say, 'Oh, forget it.'

The employees that are doing government work in these areas have lots of mechanisms for things to be slowed down, or to get stuck in bureaucracy as a form of resistance.

Do you hear your work or your colleagues' work taking on a different tone now that Trump is president?

I feel a responsibility to be more engaged, maybe even put off some of the longer-term initiatives I have in the works and focus on what's happening now, and trying to have an impact in the current situation. It's a very delicate, precarious situation right now.

There's a need for us all to be paying attention, to be trying in whatever ways we can to speak up about the dangers of ignoring, diminishing, or dismissing the decades of work that have been done in the field of climate science.

What can the rest of us do? I hear so often that an individual's efforts won't make much of a difference in addressing climate change. What can we do?

Divestment. I think the university has a responsibility to stand up for scientific integrity, because it's crucial to the basics of what our university is.

The fossil fuel divestment movement is a way for universities to make that statement. We also know from the universities that have divested that it doesn't hurt their bottom line, although that's what the concern is.

It's something tangible that universities can do and should do, and there's an opportunity for Northeastern to be a leader in this regard.

Having the courage to stand up and say, 'That is unacceptable,' is what we all need to do in whatever ways we can. In a respectful way, too. We need to engage in productive, constructive ways that hold up the integrity of science, information, and research.

BY ADANYA LUSTIG, LINGUISTICS, 2018

DESIGN BY ANNA LI, BEHAVIORAL NEUROSCIENCE, 2019

THE BLUE REVOLUTION

The rise of modern land-based and open-water aquaculture

BY LUCAS COHEN, MARINE BIOLOGY, 2019

DESIGN BY MEGAN MCGUIRE, DESIGN, 2020

In early January, the National Oceanographic and Atmospheric Association (NOAA) announced its intent to expand aquaculture in the Pacific – namely, the waters surrounding Hawaii and other Pacific islands – by opening federal waters to fish farming. NOAA's decision follows a shifting trend in the some of the agency's agendas: a move towards aquaculture-focused policies and investments. The decision to open island waters in the U.S. came shortly after a NOAA aquaculture initiative in the Gulf of Mexico that made its offshore waters available.

Aquaculture is becoming increasingly attractive for countries seeking to increase their net yields for fish and other economically relevant marine foods like shellfish – a direct consequence, no doubt, of the decline of industrial fishing practices in the ocean. Catches are declining, and reported catches are often wildly inaccurate.

Why? It seems that marine fisheries are failing on two fronts. First, fisheries simply don't catch as many fish as they used to; though some species or population stocks are increasing, catches are declining on a global scale. Second, industrial fisheries profit much less per fish caught. As fish populations dwindle, it gets harder to find and collect them – thus, fisherman have had to make large-scale technological adjustments like better sonar and GPS systems, temperature sensors, beeper buoys and fish finders, and larger fleets of heavily-equipped ships. All of these improvements come with a substantial price tag attached, but are necessary to compete in an industry that consistently struggles to meet catch quotas – at which point, fisherman tend to lose their jobs and the industry stagnates.

> "The problem with aquaculture is that – depending on the species farmed and the methods utilized– the negatives often outweigh the positives."

With aquaculture comes the promise of consistent, profitable harvests and fishing practices that are ideally truly sustainable. Aquaculture already provides welcomed jobs and revenue, and, in the United States, mitigates the seafood trade deficit. Farmed fish already account for a significant portion of seafood production in the U.S. – about 19 percent – and that number is growing. Worldwide, almost 50 percent of all seafood comes from aquaculture. With this unprecedented growth, the industry aims to reduce pressure on wild stocks and simultaneously satiate the world's hunger for seafood. This proliferation of aquaculture has been dubbed the "blue revolution."

The problem with aquaculture is that – depending on the species farmed and the methods utilized– the negatives often outweigh the positives. The method through which marine organisms are farmed is especially important. Closed land-based approaches are generally considered less risky, while open-water aquaculture systems are thought to be more troublesome, Conservationists and researchers alike worry that offshore enclosures severely alter the surrounding environment through excessive nutrient enrichment and marine eutrophication, increased microbial activity as a result of waste deposition, and spread of disease to wild populations.

It's hard to find the ideal species since there are multiple parameters to consider. One of aquaculture's benefits is reduced pressure on wild populations, but farming carnivorous fish like salmon can lead to paradoxical aquaculture practices like using wild-caught fish to feed captive fish, which brings into question the sustainability of salmon farming.

Moreover, aquaculture often threatens the environment through habitat destruction and disease introduction. Shrimp farms in Thailand, for instance, are infamous for having demolished over half of the country's mangroves to make space for farms, and then profusely releasing pollutants into the surrounding sea – that is, primarily waste products of the shrimp themselves and their feed. Diseases are also a serious concern for fish farms. Much of Thailand's profits from shrimp production are fed back into the system through antibiotics to treat parasites like Hermatodinium, which proliferates inside its host before bursting out in a cloud of smoke, is of growing concern to both aquaculture and wild fisheries around the world.

Of course, with proper management and extensive scientific research, sustainable open water aquaculture is, at least to some extent, a real possibility. One final concern, however, is that aquaculture might not be able to fully match fish production in the ocean. This should act as a warning; we can't just turn our heads away from dwindling wild stocks – ultimately, it will likely be a combination of sustainable aquaculture and industrial fishing practices that saves us from collapse.

Aquaculture shows great promise, and there is no doubt that, as an industry, it has matured immensely in recent years. The "blue revolution" is happening for a reason: we've acknowledged the importance of finding a way to alleviate the environmental pressures associated with fishing and simultaneously maintaining a thriving market for seafood. Aquaculture certainly has its problems – but it's a very real, feasible way to maintain one of the world's most precious resources.

PHOTO BY FLICKR

The Next Generation of Revolutionaries

BY SHEINA RAJKUMAR, BIOLOGY, 2017

DESIGN BY KRISTI BUI, COMPUTER SCIENCE, 2020

Throughout history, countless scientists have become famous through their revolutionary ideas and theories. Many of these theories and experiments are still studied and talked about today. Unfortunately, a recent survey found that 4 out of 5 Americans could not name a famous and living scientist from our generation. Those who were able to think of one named Stephen Hawking, Jane Goodall and Neil deGrasse Tyson, some of the only household names of the past 20 years.

Who exactly is the Einstein of the 21st Century? There are thousands of scientists doing great things every day. Science News recently listed the top 10 scientists to watch out for in 2016 and going forward. Each of these scientists were nominated by a Nobel Laureate or a member of the National Academy of Sciences, and each of them has a varied mission and repertoire of accomplishments. Hopefully soon, they too will become household names. Here's a few examples:

Aneil Agrawal

Aneil Agrawal is a distinguished professor at the University of Toronto in Evolutionary Genetics. He has worked tirelessly to provide data that supports the idea that the desire to adapt to new environments prefers sexual over asexual reproduction in all fruit flies. Agrawal has also questioned the evolution of sex, and why harmful mutations form and accumulate over time. His research has mainly concerned fruit flies and their struggle to adapt and survive in the presence of mutations and harmful genes.

Phil Baran

Phil Baran is a professor in the Chemistry Department at the Scripps Research Institute in La Jolla, California. Baran has mentored countless chemists, and has created various chemical pathways to construct synthetic complex molecules that are the precursors to flavorings, pesticides, and medications. From his work, hundreds of papers have been published documenting quick routes to concocting synthetic molecules. Currently, Phil Baran works with major pharmaceutical companies such as Pfizer and Bristol-Myers Squibb to create pathways to synthesize molecules faster that can be used in various medications.

Jessica Cantlon

Jessica Cantlon is an assistant professor at the University of Rochester in the Brain and Sciences Division. Cantlon is working to determine how humans can comprehend numbers and from where our ability to do so stems. Her work will eventually be used to construct new curriculums for children on the nature of the brain and how we can communicate numbers so they are better understood. Cantlon has identified a type of "protocounting" in baboons. Baboons can keep track of amounts of peanuts, suggesting that these animals have the ability to estimate and count.

Qian Chen

Qian Chen is an assistant professor at the University of Illinois Urbana-Champaign in the Department of Material Science and Engineering. Chen works with tiny molecules to determine what it truly means to be alive. She examines molecules such as proteins that work around the clock to keep organisms alive and functioning. Chen's ultimate goal is to create life from nonliving objects.

Lawrence David

Lawrence David is an assistant professor at Duke University in the Department of Molecular Genetics and Microbiology. One of his many accolades was discovering that the genes used to form proteins involved in the formation of oxygen were present thousands of years before oxygen appeared in Earth's atmosphere. David also conducted a personal study of his own microbiome, taking note of what he ate and any illnesses that occurred. He found that the microbiome in his gut fluctuates based on dietary changes, sickness, and traveling, information that is particularly useful for people with allergies and chronic illnesses, who may be able to target irregularities to problems in the gut.

Science (2013). DOI: 10.1126/science.1229625.

Association for Psychological Science (2015). DOI: 10.1177/0956797615572907.

PHOTO BY ASTRID WESTVANG

The Evolution of Natural Philosophy

BY ANDREW WINTER, PHYSICS, 2019

DESIGN BY ARCHANA APTE, UNDECLARED, 2021

Physics was not always what we know it as now. Natural philosophy, as it was called for the majority of recorded history, never used to have the quantity of cryptic Greek figures and complex numbers that physics is seen with today. One of the most famous experiments performed before the Common Era involved two sticks with a large distance between them. The Greek mathematician Eratosthenes measured the lengths of shadows at two locations in Egypt: Syene and Alexandria. The sun was directly overhead in Syene, so there was no shadow. Computing the angle with basic trigonometry, he was able to estimate the circumference of the earth. Easy, right?

> “Mankind has always had the struggle of moving away from old ideas into new ones.”

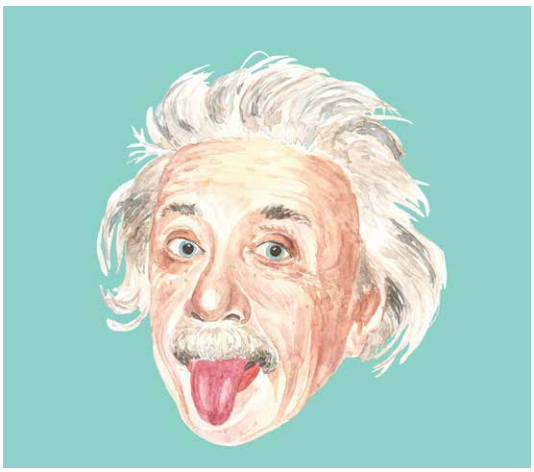
But the algebra-only days were destined to come to an end. Physics, humanity’s understanding of the natural world and universe, was revolutionized with the foundation of calculus and derivations of equations previously only found empirically. In 1687, Sir Isaac Newton’s Philosophiæ Naturalis Principia Mathematica brought forward an accurate and supported way of thinking, allowing for a transition from natural philosophy to classical physics.
Basic concepts Newton discovered, such as his well-known laws of motion, were applied to chemistry and biology, expanded to a macroscopic scale with universal gravitation, and applied to the expansion of mathematics through calculus and statistics. Soon science was booming like never before. In 1865, James Clerk Maxwell paved the way for modern physics with the first reasonable calculation of the speed of light.

Enter: Albert Einstein.

In 1905, Einstein took Maxwell’s speed of light, understanding very well that everyone accepted Maxwellian and Newtonian physics as great and successful. But Einstein thought that while the theories were close, they needed a little more spice. So he proposed that light was its own medium, and that it travels at a constant speed. This became the Theory of Special Relativity. One may approach the speed of light, but never reach it unless lacking all mass. The closer one gets to this universal speed limit, the greater the difference in how one experiences space and time compared to those moving at different velocities. Once everyone had enough time to become comfortable with the fact that the Newtonian model was merely a great approximation in comparison to Einstein’s theories, the revolution of modern physics commenced.

Mankind has always struggled with moving away from old ideas into new ones. Once we are comfortable with something, we do everything we can to stick to it. That being said, nothing short of quantum mechanics has had any strong, noticeable change since the 1920s. But what if Einstein was wrong?

We know the universe is expanding, and a new theory proposed by Professor João Magueijo from Imperial College London states that the speed of light is not constant. Or at least, it wasn’t originally. Within seconds of the Big Bang, there may have been a higher speed of light, which would explain why the universe appears to have reached a relatively uniform temperature.



Should this now-testable theory lead to accurate results, Einstein’s theories on gravity and light will be seriously challenged for the first time, leading to alterations in how we perceive the universe.

But even if he were to be challenged, Einstein was a true physicist and would be happy to see us move beyond his ideas. “No amount of experimentation can ever prove me right; a single experiment can prove me wrong,” he once said.

Physical Review (2016). DOI: 10.1103/PhysRevD.94.101301. arXiv: 1603.03312.

Strapped for Cash

Explanations and solutions for America's science funding crisis

ARTICLE AND DESIGN BY ARCHANA APTE, 2021, UNDECLARED

Scientists have long needed funding to carry out experiments; Alexander Graham Bell borrowed money from his assistant, while Galileo's groundbreaking discoveries would have been impossible without Pope Clement VI's patronage.

Nowadays, however, there isn't enough funding to sustain the current influx of scientists. This shortage has far-reaching consequences; out of all the proposed solutions, college research aid is one of the most promising.

According to *Issues in Science and Technology*, an online journal/forum funded by universities and nonprofit foundations, the federal government increased resources for military and technical research to fuel World War II and the Space Race. Additionally, the National Science Foundation was established in 1950 to stimulate growth of research on college campuses, and the accompanying grant system encouraged the proliferation of high-quality scientists who could train graduate students, leading to an explosion of doctorates from the 1940s onwards. However, such growth was unsustainable because the government did not increase funding in accordance with the growth rate of scientists; research and development funding has remained at 10% of the federal domestic discretionary budget for the past forty years. The Trump administration, in particular health secretary Tom Price and budget director Mick Mulvaney, have pledged further cuts in research funding.

The effect is more paperwork, less science. As more researchers compete for a shrinking pile of money, the odds of one researcher winning a certain grant decrease, forcing each applicant to apply for more and more grants, which further lowers each applicant's odds of securing a grant.

Fierce research competition forces the government to exercise increased caution when rewarding grants, favoring incremental, "safer" research over risky but potentially groundbreaking work. A 2009 *New York Times* article noted that such a policy compromises the effectiveness and speed of critical cancer research; in addition, funding competition deters young scientists from pursuing burgeoning fields of study. Since grants are more likely to be awarded to elite researchers with histories of success, younger professionals without such reputations are unable to land funding. This discouragement of youth opportunity is ironic given the recent emphasis in Washington, D.C. on STEM educations and opportunities for children.

Facing grim competition, some scientists and policymakers advocate turning to private donors for research funding. Private funding once supported pure important research, such as AT&T's Bell Lab's Nobel Prize-winning work on the Big Bang in 1964. Today, however, companies will only fund profitable work. In a world of privatized funding, few discoveries would be made to increase basic knowledge; we wouldn't be investigating the Higgs Boson particle or photographing planets. Instead, all research would be conducted in secrecy as each company tries to prevent others from stealing its innovations. Such a paranoid atmosphere would destroy the honest innovation critical for genuine scientific progress.

Private funding also poses the danger of biased research, when companies or institutes pressure scientists to falsify data or compromise research tactics to suit an external agenda. There is mounting evidence that funding bias does occur, with widespread ramifications for the public.

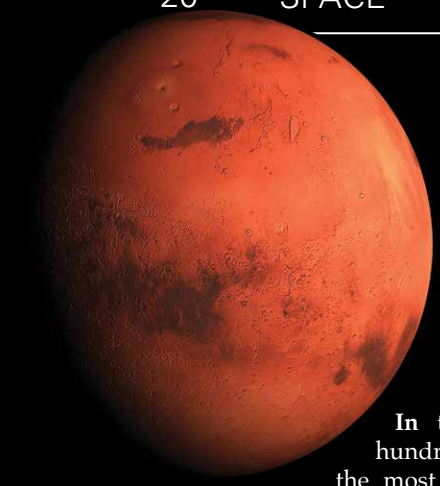
With federal aid in short supply and private funding setting the stage for corruption, university aid could be an answer. After all, universities produce the influx of scientists which made the system unsustainable in the first place.

> "With a few modifications to our current system, we can ensure that science continues paving the way for a healthier, more informed future."

Currently, colleges lure PhD-wielding professors with high initial funding packages in the hopes that professors' high-quality research results will attract further federal funding after their packages are used up. But cutthroat competition for funding calls for a systematic revision: universities would give researchers lower initial packages but support the scientists throughout their entire careers, filling funding gaps when necessary. According to *Issues in Science and Technology*, colleges would need to explain to potential hires the benefits of a career-long funding plan over a larger startup package, since many professors today see a larger initial funding package as more desirable.

A smaller startup package would require professionals to share labs, which would ideally stimulate collaboration and networking amongst researchers and students. Centering research in a collaboration-driven college laboratory, with its knowledge-seeking culture and less secretive research setting, could help mitigate biases resulting from a funding source with extraneous motives. Researchers would also need to diversify funding sources to supplement university aid, a practice which could encourage scientists to tackle a wider variety of issues.

A university-based approach to research funding is an imperfect but promising solution to a pressing problem. With a few modifications to our current system, we can ensure that science continues paving the way for a healthier, more informed future.



ELON MUSK

Manifest destiny in the new space frontier

BY MATT KALPIN, BIOENGINEERING, 2021

DESIGN BY KYRA PERZ, CHEMISTRY, 2020

In the year 2062, you and two hundred random strangers board the most powerful rocket to have ever been produced, a rocket so powerful it doubles the thrust capacity of NASA's largest rocket, the Saturn V. As you board, your body prepares for the over 28 million pounds of thrust the spaceship will produce in order to carry two million tons of cargo out of Earth's atmosphere. This interplanetary spaceship will embark on an approximately 60-80-day journey through the empty vacuum of space until reaching its destination. You have bought yourself a one-way ticket to the newly founded Mars Colony, only 40 million miles from Earth. Welcome to your new home.

> "Humanity is built upon the foundation of innovation and great thinkers. Outrageous yet confident in his endeavors, Elon Musk has dedicated his life to changing the future for the human civilization."

Although this absurd scenario appears to be taken straight out of a futuristic Sci-Fi novel, these are truly the ambitions of one of the greatest innovators of our time, Elon Musk. The CEO and founder of Tesla and SpaceX is set on changing the course of the future for the human civilization by turning us into a multi-planetary species. In a Ted-talk interview, Musk responds to ridicule of his far-fetched ideology of being the first individual to turn humans into a space-faring species, "I really think there's a fundamental difference, if you sort of look into the future, between a humanity that is a space-faring civilization, that's out there exploring the stars, on multiple planets, and I think that's really exciting, compared with one where we are forever confined to Earth until some eventual extinction event". As paranoid as Musk may sound, his success is evident and can be measured by his 2.6$B contract from NASA allowing SpaceX to fly commercial crew and astronauts. Other companies have contracted SpaceX to oversee their projects such as the most recent Iridium-1 and Iridium NEXT missions designated to launch 10 of an upcoming 70 satellites in an effort to provide 100% global communication. These launches however are just small strides towards colonizing Mars.

The principal cause of dilemma in Musk's ambitions is just a simple fact: traveling to Mars is expensive... and to be precise, 10$ billion. Musk, however, proposed an interesting hypothesis to counter this source of failure by manufacturing re-usable rockets. In fact, SpaceX was the first to successfully produce a rocket that was capable of self-landing upright after being launched. This rocket type known as "Grasshopper" pioneered a generation of new ideas for the company in 2013. By using this mechanism, Musk estimates to cut the cost of a one-way Mars ticket down to $200,000, equivalent to the average cost of a household in the U.S. The Interplanetary Transport System is designed on rocket reusability, with a lifespan of 12 uses per ship capsule and 1000 uses per booster. In comparison to the Falcon 9, SpaceX's largest rocket, the ITS is propelled by 42 Raptor engines, each three times as powerful as one of the nine merlin engines installed in the Falcon 9. If Musk proves his far-fetched motives are possible, humans can expect to be shuttled to the red planet within the next decade, and establish a sustainable colony within 50-100 years.

Colonizing the red planet within the next decade is seemingly impossible, however thanks to non-expendable robots, Musk may actually meet this deadline. Artificially intelligent robots could hold the key to the vitality of the mission, such as the R5 series produced by NASA. These prototype robots are expected to survive and operate in the harshest conditions, and establish landing sites for human astronauts. In an exclusive interview with Dr. Taskin Padir, a computer and electrical engineer here at Northeastern who worked on the R5 "Valkyrie", he proposed thoughtful insight of the impact of his research on space exploration, "Our research, if you write a piece of code or if you create a new technology, and if that new technology or some version of it makes it to mars when the time comes in the 2030s, what else can we want?"

Humanity is built upon the foundation of innovation and great thinkers. Outrageous yet confident in his endeavors, Elon Musk has dedicated his life to changing the future for the human civilization. A quote from Eugene Cernan, the last man who walked on the moon and recently passed, perfectly summarizes Elon Musk's inspiration, "Curiosity is the essence of human existence. 'Who are we? Where are we? Where do we come from? Where are we going?'... I don't know. I don't have any answers to those questions. I don't know what's over there around the corner. But I want to find out".

ATTEMPTED SPACE-TIME COUP

BY JAMESON O'REILLY, PHYSICS AND MATH, 2019

DESIGN BY KYRA PERZ, CHEMISTRY, 2020

Among the four fundamental forces of nature, gravity i unique in a number of ways. While the other three, the electromagnetic, weak, and strong forces, are described by quantum mechanical theories and have fundamental particles corresponding to them, our current best understanding of gravity, general relativity, seems to be mathematically incompatible with quantum mechanics. Theorists have spent decades attempting unsuccessfully to complete a unified theory of everything by combining general relativity with quantum mechanics. Particle detectors have failed to find a graviton, a force-carrying particle analogous to the photon for electromagnetism, and string theorists have yet to produce a testable prediction. Although it was the first to be identified and studied, gravity has thus far resisted all efforts to definitively unify it with our other theories.

These efforts have usually involved adding either a gravitational component to the Standard Model of particle physics, such as the graviton, or an underlying explanation such as string theory. Grand Unified Theories like string theory propose underlying structure that can explain both gravity and quantum mechanics. As previously mentioned, both of these examples have their own practical problems. Unification of theories usually simplifies things whereas these additions arguably make our universe more complex.

> "We should be excited about this news because it is, after all, exciting, but a healthy scientific process requires skepticism and due diligence."

Fortunately, another possibility was suggested by Professor Erik Verlinde of the University of Amsterdam in 2010. Rather than describing gravity as a fundamental force, he proposed that it was an emergent phenomenon resulting from the evolution of microscopic bits of quantum information, similar to how temperature arises from the movements of atoms and molecules. Instead of adding something new, he was able explain gravity, including deriving the equations of general relativity with the appropriate approximations from quantum mechanical first principles.

The most important difference in the predictions of Verlinde's new theory is that at massive scales, the strength of the gravitational force will be inversely proportional to the radius instead of the square of the radius. In simpler terms, at very large distances, gravity should be slightly stronger than general relativity or Newtonian mechanics predict. While this might seem strange at first, there are actually already well-documented cases of stronger gravity than expected. Verlinde's theory can explain the deviations usually attributed to dark matter from first principles rather than introducing a new parameter and tuning it to get the desired predictions.

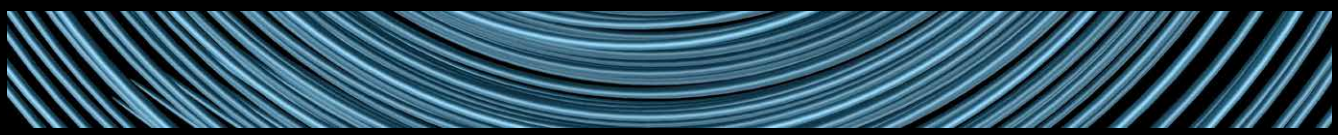
One example of this is the bending of light around galaxies, known as gravitational lensing. The light bends more than would be expected based on the mass of observable matter in these galaxies, which has traditionally been attributed to the presence of dark matter. Recently, however, a team led by Margot Brouwer of the Leiden Observatory compared the gravitational lensing effect observed for over 33,000 galaxies to the predictions made by Verlinde's theory and found that they agreed well.

So, is it finally time for the next big scientific revolution? The short answer is probably not. An even shorter answer is no. While the evidence did agree with the theoretical predictions, this behavior could also be explained by dark matter. The theory has also faced a lot of criticism, and is currently only applicable to systems that are isolated, static, and spherical, which covers only a tiny portion of the universe.

We should be excited about this news because it is, after all, exciting, but a healthy scientific process requires skepticism and due diligence. Verlinde's theory agrees with at least one experiment and has distinct advantages over previous attempts at unification of gravity and quantum mechanics, but even if the theory had no issues, it would be irresponsible to herald this as the Next Big Thing so soon. Like Newtonian mechanics, general relativity, and every other successful theory before it, Verlinde's version of gravity has passed its first test. However, when it comes to gravity, the first test is just the beginning.

Verlinde, E. J. High Energ. Phys. (2011) 2011: 29. DOI:10.1007/JHEP04(2011)029

PHOTO BY SHUTTERSTOCK



THE EVOLUTION OF REVOLUTION

Changing conceptions of planetary motion through the ages

BY MATTHEW DEL MASTRO, BIOLOGY, 2017

DESIGN BY CATU BERRETTA, COMPUTER SCIENCE, 2020

They are like wandering stars," the New Testament proclaims of teachers spreading false doctrines of Christianity, "doomed forever to blackest darkness." To the original audience of this ancient text, the imagery of "wandering stars" would have been immensely powerful. Early observers, believing themselves to reside at the unmoving center of the universe, could explain the movement of most stars intuitively. Day after day, the stars rise from the east and set in the west, just as would be expected if they were orbiting around the Earth. However, some celestial bodies refused to conform to this convenient pattern. These objects typically moved eastward across the sky, but sometimes they would abruptly backtrack and move west for a time, only to just as suddenly switch back to an eastward trajectory. The Greeks termed these enigmas "wandering stars," or asteres planetai. While the English-speaking world would later know them simply as "planets," the nature of their mysterious motion would continue to perplex the greatest minds in astronomy.

Philosophical Origins

One of the key ideas driving early Greek investigation into planetary motion originated not with an astronomer or mathematician, but with the great philosopher Plato. His beliefs about the perfection of heavenly bodies convinced him that the stars must move in perfect circles around the central and stationary Earth. He was even said to have issued a challenge to contemporary astronomers to provide a mechanism to support his deduction. In years to come, numerous astronomers would take up the task and provide inventive explanations to reconcile their observations with Plato's ideals. The most popular model placed the Earth in the center of the universe and fixed the stars to a massive celestial sphere in constant circular motion around the Earth. To explain the "wandering stars," every planet was also placed on a rotating sphere, each one separate but connected to the larger celestial sphere. The rotations of each of the different spheres thus combined to produce the complex wandering motions of the planets. The model was philosophically elegant, but it undeniably fell short when it came to making accurate predictions about the strange movements of the wandering stars. Generations of astronomers, including such luminaries as Aristotle, would struggle to no avail to make this system operate with predictive power.

Ptolemy: Accuracy through Epicycles

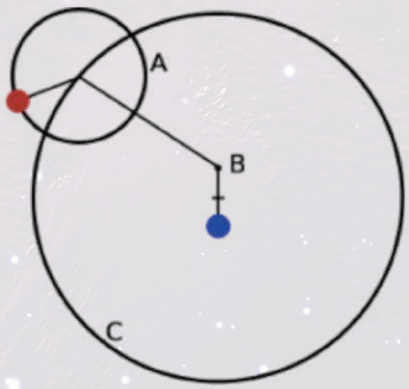
Still, astronomers were adamant that an explanation could be found that would unify philosophical ideals with actual observations of the planets. The t of these efforts was proposed in the first century C.E. by an astronomical titan of antiquity, Ptolemy. His magnificently complex mechanism explained planetary motion by incorporating the concept of an epicycle, the pattern that results when a platnet orbits around a point that is in itself orbiting around the center of the universe. For those accustomed to the modern view of the solar system, Ptolemy's complex model might leave one's head spinning faster than the celestial bodies in his epicycles. But it offered something far more valuable than simplicity: predictive power. In Ptolemy's time, people from all walks of life relied on knowing the positions of the planets for the astrological readings that they believed could explain events on Earth. Ptolemy's model was incredibly accurate, and its assumptions lined up with everything that contemporaries believed about Earth's place in the universe. He seemed to have finally achieved the long-sought unison of philosophy and observation.

Copernicus: A Reactionary Revolution

Even as civilizations rose and fell around it, the seemingly indisputable accuracy of the Ptolemaic model firmly secured it within the worldview of educated westerners. It would be over one thousand years before a revolution in theories of planetary motion. The instigator, Nicolaus Copernicus, ironically incited this revolution while attempting to justify his conservative ideals. Copernicus was steeped in the philosophy of Aristotle and Plato, and he was troubled by the fact that Ptolemy's model did not include perfect circular motion in the heavens. Copernicus set out to restore uniformity to planetary motion and to do so he was willing to sacrifice one of the key astronomical assumptions of the past millennia: the centrality of a stationary Earth in the cosmos. Allowing the Earth to move in orbit around the sun alongside the other planets gave Copernicus an alternate way to explain the strange backtracking of the planets. He achieved similar predictive power to the Ptolemaic model while incorporating his all-important uniform circular orbits. This was a revolutionary approach, but the conservative Copernicus did not extend such inventiveness to the rest of his model; he opted to retain many key elements of the Ptolemaic model including the complex epicycles. Still, the idea was radical enough to encounter staunch resistance. It would take another brilliant man and an innovative new technology to drive its acceptance and transform the way planets were perceived.

Galileo and the Acceptance of a New View

In Italy, Galileo Galilei was the first to turn the eye of a telescope towards the heavens and he found that the enigmatic planets had even more mysteries in store. After observing the phases of Venus and the moons of Jupiter, phenomena that should have been impossible under the Ptolemaic system, Galileo came out in favor of Copernicus. Despite Church persecution, the evidence in his widely read books ultimately proved decisive in shifting the public's perception of the planets. When Galileo's contemporary Johannes Kepler conclusively showed that the planets orbited in ellipses rather than perfect circles, Plato's astronomical ideas finally faced the death knell. These breakthroughs provided a definitive explanation for the strange movements of the planets, and in the process they set in motion the Earth that had remained fixed in place in the minds of so many generations. Though the eccentric movement of the planets may have troubled ancient observers, they would have been even more shocked to find that they themselves were hurtling through space on a "wandering star."



Simplified depiction of Ptolemaic model. A planet (red dot) in an epicycle (A) travels on an orbit (C) around the center of the universe (B), which is located next to the stationary earth (blue dot).

REVOLVING SPACECRAFT

BY SAMANTHA GLASSNER, MECHANICAL ENGINEERING, 2020

DESIGN BY ANNA LI, BEHAVIORAL NEUROSCIENCE, 2019

If you have watched as many sci-fi movies as I have, you will notice that there are many ways that directors choose to portray artificial gravity. It may seem normal watching the crew of the USS Enterprise (Star Trek) or Millennium Falcon (Star Wars) in the bridge or cockpit, respectively, sitting at their control panels – but if you take a step back and think about it, this is not how our astronauts live their daily lives. On Earth, we have gravity to hold us down and give us the feeling of weight, but the scientists on the International Space Station (ISS) live in the wonders of microgravity.

Many think the feeling of weightlessness astronauts experience on the ISS is simply due to its orbital distance from Earth. In reality, this microgravity environment is created because both the astronauts and the ISS itself are falling back to Earth at acceleration 89 percent of Earth's gravity. This feeling is similar to going on a rollercoaster that brings you up to a high height and then drops beneath you, giving you a momentary feeling of weightlessness. Since the ISS in in continual orbit around the Earth, it keeps falling but never comes back into Earth's atmosphere, locking astronauts into a continuous feeling of weightlessness, or as it's commonly referred to, zero gravity. In most sci-fi movies, though, characters have their feet planted soundly on the floor of their spacecraft just as we do on Earth's surface. Many movies and TV shows, like Star Wars and Star Trek, gloss over how their spacecraft pull off this magnificent feat of artificial gravity and simply reference devices like "artificial gravity generators" on board. For veteran viewers like myself, this may seem like a cop-out, but if the characters are living in a theoretical universe where things like "warp drives" and "hyperdrives," Star Trek and Star Wars respectively, also exist – imagining that scientists have built a device capable of turning gravity on and off with the flip of a switch doesn't seem so far-fetched.

Other sci-fi movies set in outer space decide to try and make their artificial gravity techniques seem more feasible by having their entire spaceships rotate. As it turns out, this is a much more realistic portrayal of how spaceships might create artificial gravity. But how would artificial gravity in a revolving spaceship work?

The forces that could hypothetically generate artificial gravity on a spinning spaceship are the same forces that act on you when you are on carnival rides like Gravitron, where passengers stand with their backs against the inside of a large exterior ring. Once the ride starts spinning fast, you can feel yourself getting pushed back against the ring. No matter what angle at which the ride tilts, you remain safely pressed against its inside. This force you feel pushing you against the ride is called a centripetal force, which is generated from the centripetal acceleration that is acting on your body towards the center of what you are rotating around. The spinning spacecraft you see in sci-fi movies could theoretically generate artificial gravity by this same principle.

If you want to read more about the wonders of gravity, I recommend picking up a book on anti-gravity. I promise it will be impossible to put down.

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Book Review: October Sky

The key component to rocket fuel is sweat

BY VIVIAN LEE, COMPUTER SCIENCE AND BUSINESS, 2020

DESIGN BY ANNIE LEE, DESIGN, 2019

A world that cares only for football and coal-mining would seem pretty dull, especially if you had zero interest in either of them. That world was Homer Hickam Jr.'s reality growing up in the small town of Coalwood, West Virginia in the 1960s. The town's very name spoke for itself. Without any hopes or dreams of receiving a football scholarship to go to college, Hickam seemed trapped in Coalwood with a predetermined future: working for the mining company like every other family in town, forever living and breathing in the coal dust that would eternally cover Coalwood and all of its occupants.

But in 1957 when the Russians successfully launched Sputnik 1 and Hickam looked up at the sky from his backyard, he saw more than mankind's first step towards exploring the final frontier. He saw an opportunity. Sputnik gave him hope that there was indeed something out there for him that wasn't coal mining and at the time, that was enough.

> "I had discovered that learning something, no matter how complex, wasn't hard when I had a reason to want to know it." - Homer Hickam Jr.

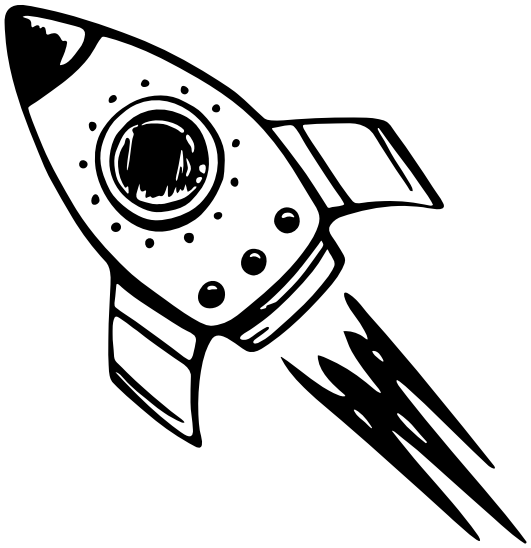
On that day Hickam decided to embark on his own space race, only his rival would be scarier than the Russians: the doubts of his friends, family, and even himself. And just like the scientists at NASA, failure was not an option.

Throughout his memoir, Hickam recounts the various obstacles he and his friends - famously dubbed the Rocket Boys - faced. They endured both physical and mental challenges: going beyond their high school's subpar mathematics courses, teaching themselves calculus and differential equations, even facing multiple brushes with death along the way. Nothing would prevent the Rocket Boys from carrying forward and progressing toward their ultimate goal. Their simple aspiration to build model rockets that would actually fly, quickly evolved into learning how to maximize the height of their rockets' trajectories, attempting to climb higher and higher into the sky each time. Their ambitions eventually led to a first place project at the National Science Fair, a competition Hickam had initially regarded with trepidation for fear of not being smart enough to enter, much less win.

I loved Hickam's depiction of the difficult relationship he had with his father growing up. Like the majority of Coalwood, Homer Hickam Sr. knew two things: football and coal-mining. Since his son wasn't interested in either, he often found it difficult to relate to and connect with him. However, even though they did not always see eye-to-eye, Hickam masterfully illustrated the truths and strengths behind both of their characters in a way that made no one look like the antagonist. Despite their differences, Hickam and his father shared the same stubborn enthusiasm for the things they loved, the aspect that became the driving force behind their success in their individual fields.

One of my favorite moments in the story was when Hickam, after spending months petitioning to convince his school to offer a Calculus course, was denied entrance into the class. As a trial run, the school had decided to choose the top five students from their current math course to participate. Hickam was the sixth. Rather than simply being dejected and calling it quits, Hickam discovered an old advanced mathematics textbook on his father's bookshelf and quietly began teaching himself calculus and differential equations. Later on when Hickam was presented with another textbook on the science behind designing missiles from his chemistry teacher, she told him: "All I've done is give you a book. You have to courage to learn what's inside it."

Hickam's story inspires readers to chase what they are interested in and passionate about, regardless of what anyone else might say or think. He emphasized the importance of education, relentless hard work, and perseverance. "I had discovered that learning something, no matter how complex, wasn't hard when I had a reason to want to know it", Hickam explained. His extraordinary journey, recounted in this exceptionally well-written novel, encourages every one of us to not to have life all planned out, but rather to find something of genuine interest and run as far as possible with it. After all, if a rocket boy predestined for the coal mines could make even the captain of the football team jealous and bring an entire town together in the process, anything is possible.



VIVA LA NEWTON

How the application of basic physics principles is rewriting cancer research

BY EMILY ASHBOLT, BIOMEDICAL PHYSICS, 2017

DESIGN BY SHRADDHA B. KAKADE, JOURNALISM, 2019

The scientific community has always known the value of diversity. From genes to forests, monocultures are self-destructive and don't inspire new progress, evolution or strength. But there are still many places in the research world where lines between fields are drawn - and in some cases, these lines can cause people to lose their lives.

Physics could be called the "purest" of the sciences, and because of this, it can sometimes seem distant and unrelated to much of the science seen going on day-to-day. But everything that can be seen - and much of what cannot - is governed by its most basic of principles. The Newtonian physics that hides in everything has for a long time been taken for granted by much of the scientific community and not seen as a source of new information or cause in the face of the incredible advancements made in neuroscience, biology, chemistry, or medicine. There is growing evidence, however, to suggest that overlooking the basics may be a gross oversight.

One avenue where the re-discovery of Newtonian principles has been making a remarkable reoccurrence is in the field of cancer metastasis research. Metastasis has for a long time been a known – and feared - phenomenon. Scientists and doctors have long observed cells of all different types of cancers make their way into the body's blood stream and use it as a superhighway to infiltrate other organs. For a while, it was believed this was only occurring on a cell-to-cell basis. Discoveries in the past two decades have shown that it is often small networks of cancer cells travelling in packs that seed much of the metastasis. How this was possible - how cancerous cells could work together to travel to different parts of the body - had not been explained.

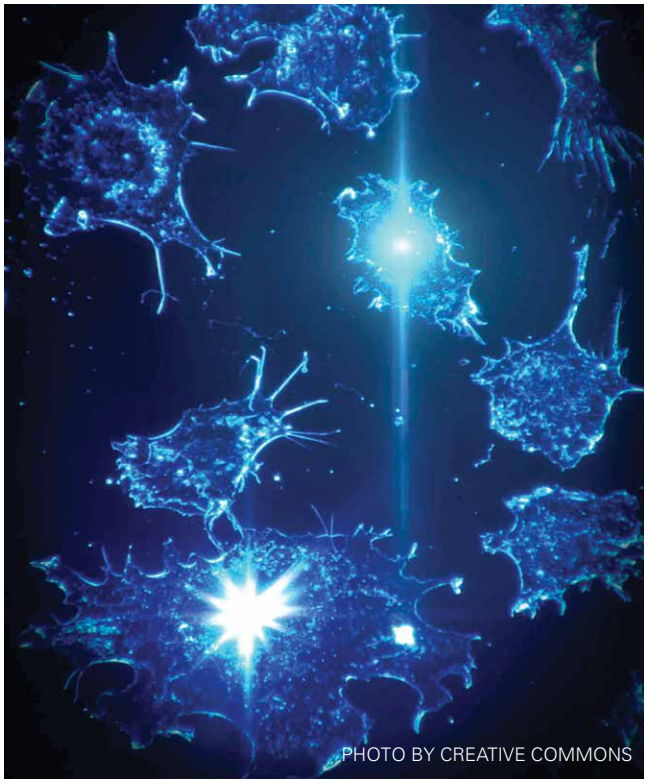


PHOTO BY CREATIVE COMMONS

Harvard professor Jeffrey Fredberg started unraveling the mystery when he wrote a paper describing a phenomenon exhibited in some lung cells he had been studying. Fredburg saw the cells get so tightly packed together that they started behaving like one super-unit, like wet sand sticking together. Bioengineer Peter Freidl read this paper and realized that this sounded a lot like the behavior he had seen in the cancer cells he was studying.

This cell jamming, to physicists, is actually seen as a sort of phase transition. Syracuse physicist Lisa Manning modeled this process. This model put numbers to this phenomenon in a way that to Manning seemed "ridiculously strict". The order number, the number that quantifies the internal structure of the system in the model, revealed a very simple over/under shape index. When the shape index is equal or lower than 3.81, the tissue will behave like a solid. Higher than 3.81, and the tissue will behave like a fluid.

Other scientists have taken these discoveries and used them in diagnosis. In Germany, physicist Josef Kas is looking at whether metastasis can be predicted by analyzing the amount of "jammed" cells in a tumor sample. His idea is that the more "fluid-state" cells there are, the closer the cancer is flooding into the blood and the rest of the body.

Cells are obviously not passive objects like grains of sand. Cells live, react to the environment, and change their morphology throughout their existence. One flaw in the current model of cell phase is that it does not consider the interactions that cells have with the other cells around them .However, jamming cells do have the potential to explain aspects of the metastatic process, and if nothing else, have got more and more physicists interested in the biomechanics of cancer, where their expertise and insight can breathe fresh air into old problems.

Diversity breeds progress: different ways of approaching the same problem means that obstacles don't cause everyone to get stuck in the same place. As scientific communities become increasingly interdisciplinary to keep up with a rapidly changing world, physicists are determined to make sure that their dry math keeps its toes wet in the newest discoveries, and the rest of the scientific community would do best to listen, both to them, and to all other informed voices trying to be heard.

The PainKILLer

BY DAVID LU, PHARMACY, 2021

DESIGN BY YU CHENG, GRAPHIC AND INFORMATION DESIGN, 2018

In 2012, 259 million prescriptions were written for opioid painkillers, which is more than enough to give every American adult their own bottle of addictive pills. In 2011, SAMHSA statistics estimated that about one in three hospital emergency room visits involving non medical drug use involved narcotic pain relievers. The widespread distribution and concomitant abuse of these highly addictive and life-crippling drugs has led to the modern day Opioid Abuse Epidemic, which is responsible for over twenty thousand lethal overdoses according to 2015 statistics from the American Society of Addiction Medicine. Though programs have been put into place by the National Institute of Drug Abuse to combat drug addiction through research on pain and alternative pain medications, development of overdose antidotes such as Naloxone, rehabilitation treatments, and tightened FDA regulation, the epidemic shows little to no signs of slowing down. As grimly stated by CDC Director Dr. Tom Frieden in the March 2016 edition of the New England Journal of Medicine, "We know of no other medication routinely used for a nonfatal condition that kills patients so frequently."

Opioid Painkillers

Opioid painkillers are some of the Food and Drug Administration's most highly controlled substances. Often prescribed for patients with chronic pain, these natural and synthetic narcotics are illegal to manufacture, dispense, and possess without a valid prescription and/or medical condition because of their dangerous side effects and notoriety for causing a euphoric "high." The most popular include morphine, OxyContin, Vicodin, and, most notably, Promethazine-Codeine cough syrups, which are used to make "lean" and "purple drank" concoctions as depicted in Hip-Hop culture and music. These painkillers are increasingly easy to obtain and abuse in the tablet, liquid, and syrup form. Many opioid-derived products do not require a prescription but are equally subject to abuse. They are generally safe when used as prescribed, but can lead to drug dependence, addiction, and ultimately, fatal overdose.

How does it work?

Opioids attach to pain receptors located on neurons and obstruct the path of pain signals from reaching the brain. The receptors, also known as mu opioid receptors, span pain-responsible neurons (nociceptors) on the spinal cord, the brain, and all across the body. With extended use and abuse, the same amount of drug does not achieve the same original sensations, which is a phenomenon called tolerance. As a result, users have to increase their dosage to achieve the same relief while simultaneously becoming more sensitive to pain. These dangerous side effects often encourage opioid abusers to, instead, use Heroin, a cheaper and more accessible option that operates in the same way but produces a stronger "high". In fact, based on a 2013 study, 4 out of 5 heroin users began by abusing opioid painkillers. However, thanks to recent research findings, the possibility of an effective solution lies in the near future.

A New Hope

In a recently published study from Stanford University Medical School, researchers found that drug tolerance and heightened pain sensitivity may be caused by opioids' effect on peripheral pain neurons located in the body, not the spinal cord and brain. Working in mouse models, they injected a commonly used opioid painkiller, morphine, into both normal mice and mice that had their mu opioid receptors "knocked out" in their peripheral pain neurons. After running through a number of pain tests, the researchers found that acute pain relief lasted longer in the mice lacking the mu opioid receptors than normal mice. This allowed the researchers to conclude that these specific receptors are responsible for opioid tolerance and that these pain-relieving properties must occur primarily in the brain. With this finding in mind, the researchers then tested morphine co-administered with methylnaltrexone bromide, a drug that specifically blocks mu opioid receptors in the periphery pain neurons. They found that this method caused no significant difference in pain relief, but almost completely eliminated tolerance and increased pain sensitivity. As methylnaltrexone bromide is already prescribed to reduce opioid-induced constipation, the drug is safe to use in patients. The findings of this mouse study now awaits testing in clinical trials in hopes of further understanding the science behind these dangerous side effects.

The implications of this study are enormous; if peripheral pain neurons are indeed responsible for opioid induced side effects, the door to effective drug treatments and co-administration therapies targeting these specific receptors is open for further exploration. In other words, if opioids can be safely administered without causing tolerance and heightened pain sensitivity, we can one day render opioid addiction as a relic of the past.

As stated by CDC Director Dr. Tom Frieden in the New England Journal of Medicine in March 2016, "We know of no other medication routinely used for a nonfatal condition that kills patients so frequently."

Thanks to recent research findings, the possibility of an effective solution lies in the near future.

PHOTO BY WIKIMEDIA COMMONS

Going Nuts Over New Guidelines

BY STEPHANIE WASIUK, BIOLOGY, 2017

DESIGN BY KRISTI BUI, COMPUTER SCIENCE, 2020

Growing up with allergies is no fun. You're always scared of eating the wrong thing. You have to sift through your Halloween candy and hand over all the Reese's, which make up approximately 40 percent of your entire stash, to your older sister. The school nurse is constantly calling you down to her office when your classmates bring in cupcakes to celebrate their birthdays, just to be safe.

Allergies, especially peanut allergies, have been on the rise in the US and most other developed countries for years. More kids have to face the scary fact that they need to carry around those yellow EpiPens that so brightly conceal huge needles. Allergists around the world continue to search for the proper way to treat infants so that they will not have to face these inconveniences later on in life. A recent study, called Learning Early About Peanut Allergy (LEAP), led by Alkis Togias, an allergist out of Maryland, revealed data supporting the re-writing of guidelines regarding the diets of infants
.
Previous guidelines suggested avoiding peanut-containing food products up until age 3. Since the turn of the century, many new studies have been done, with results pointing towards introducing peanut products earlier than that.

The new guidelines generated by the results from LEAP break the infant population down into three categories: infants with severe eczema and/or egg allergy, infants with moderate eczema, and infants without eczema or any food allergy. Both eczema and egg allergies have been linked to an increased risk of peanut allergy, which is the reason for taking both into consideration. Each group is treated slightly differently, but generally it is now suggested that infants be fed peanut-containing products between 4 and 6 months of age. For the more at-risk groups, it is suggested that they be fed in a doctor's office or with specific instructions.

The researchers followed up on the previous study with LEAP-ON, which involved the same children treated in the first study. LEAP-ON analyzed whether children who were fed peanut products early on and did not have allergies would develop them after abstaining from eating peanut products for 12 months. The results showed that even after a long period without exposure, there was no significant peanut allergy development.

Although each child is different, data is pointing to earlier exposure of peanut products to lower the risk of peanut allergy development. It seems we might be in for a brighter future in which every child is entitled to their entire bag of Halloween candy.

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Have You Heard? Sitting Is the New Smoking

BY MEREDITH CRAIG, PHYSICAL THERAPY, 2020

DESIGN BY KRISTI BUI, COMPUTER SCIENCE, 2020

According to The Huffington Post, "Sitting is more dangerous than smoking, kills more people than HIV and is more treacherous than parachuting. We are sitting ourselves to death." Thus, it is no wonder that the title mantra, "sitting is the new smoking," is catching on as new evidence reveals just how dangerous our sedentary lifestyles are.

Prolonged sitting, what the journal Current Cardiovascular Risk Reports is referring to as "inactive physiology," is proving to be dangerous because it is how many Americans are spending almost their entire day. Even if a person is considered "physically active" and meeting the suggested hour of exercise a day, they still may be spending up to 15 hours a day sitting, whether it is at work, driving, or in social settings. This "background" time, what people are doing when they are not exercising, is what is so detrimental to our health. According to a study from the Journal of the National Cancer Institute, for each two-hour period of sitting, a person's risk for colon, endometrial and lung cancer increases. An American Journal of Epidemiology study reveals that people who sit more than six hours a day die earlier than people who sit three hours a day or less, and a Diabetologia article shows that people who sit more can be up to two times as likely to develop Type 2 Diabetes than those who sit less. Additionally, a Journal of Physiology study reveals that sitting causes a decrease in lipoprotein lipase production, an enzyme that breaks down fat and converts it into energy, thus storing the fat instead. Furthermore, extensive sitting also causes severe muscle stiffness, which can lead to difficulties running, walking, jumping and standing later in life.

PHOTO BY JOSE ROCO

Clearly, prolonged sitting has revealed itself to have severe consequences. On the bright side, these consequences can likely be avoided with some simple lifestyle changes. It is improbable that everyone will be able to drastically reduce time spent sitting, and it may be especially difficult for students and desk-job employees. However, even slight modifications can help. Taking time to notice one's posture, getting up to stretch or taking a walk around the office to break up every hour spent sitting are good ways to start. Standing desks are ideal for people who currently spend most of their time at work sitting, but doing even some of one's work while standing instead of sitting is beneficial too. It may be surprising to find that sitting, an incredibly common lifestyle habit, is so unhealthy. Now, as Current Cardiovascular Risk Reports puts it, it is time to "be aware… sit less and stand more!"

MAKING THE CONNECTION:

Physicians designate new organ in the body

BY CICILY KREBILL, BIOLOGY, 2019

DESIGN BY KYRA PERZ, CHEMISTRY, 2020

Historically, medical schools have taught that within the human body there are a grand total of 78 organs - a fact that is now being rebuked by recent research. The mesentery, once thought to be a set of fragmented tissues that attaches the stomach, spleen, small intestine, pancreas and other organs to the abdominal wall, has been deemed the newest organ in the human body. It is also one whose function physicians know little about. Although it was recently discovered by Dr. J Calvin Coffey at the University Hospital Limerick, it is not new at all, with depictions of the mesentery dating all the way back to Leonardo da Vinci.

> “Physicians hope that future exploration of this mechanism, as well as its interaction with other organ systems, will benefit the field of gastroenterology through the improvement of diagnostics and therapeutics.”

While physicians previously knew of the presence of the mesentery, its contiguity, or continuous structure, is something new. In the years that followed da Vinci’s depiction, medical illustrators and physicians drew the mesentery in a contiguous fashion. However, starting in the 20th century, the majority of the clinical literature depicted it as fragmented. The assumption that it was a fragmented structure lead doctors to believe it was relatively unimportant until this recent discovery.

What made its identification within the body so hard is the way it varies conformation and mobility throughout the intestinal tract. In fact, its connection can only be seen when it is exposed in a certain way using surgical methods. Its contiguity was first demonstrated in a cohort of surgical patients, but is now further verified using both MRI and surgical methods.

This classification as an organ has a significant effect on the medical world as physicians approach treatment and diagnosis differently with the knowledge that it is one continuous structure. By gaining a greater understanding of the normal mesenteric shape, it will be easier to identify abnormal positioning and disease. Because of this physicians and researchers can now begin to examine what role the mesentery has in abdominal disease, as its connectivity to adjacent organs creates a direct mode of disease spread.

Furthermore, the adoption of universal nomenclature will facilitate the standardization of surgical procedures and lead to valid comparison between clinical trials. It also warrants further attention. Now that it has been classified as an organ and its anatomy has been discerned, the next step is to continue to research its function. Physicians and scientists will need to determine whether it should be viewed as part of the vascular, intestinal, endocrine, cardiovascular, or immunological system, as it plays a role in all of them. The location of the mesentery, dispersed between the intestine and the body, makes it well-positioned to receive intestinal signals and mediate local or systemic responses. Although this has been hypothesized, it is still unclear by which mechanisms the mesentery does this, underscoring the need for continued studies of the organ. Physicians hope that future exploration of this mechanism as well as its interaction with other organ systems will benefit the field of gastroenterology greatly through the improvement of diagnostics and therapeutics. There is still relatively little known about the newest organ, but one thing is certain, the depiction of its shape will continue to advance the medical field.

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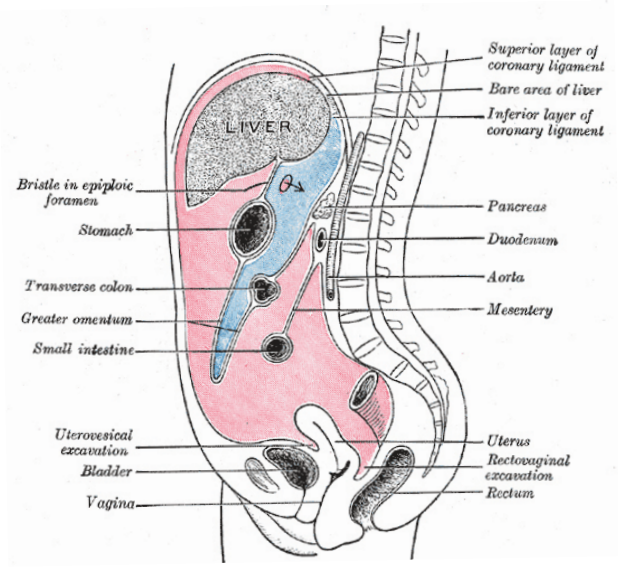


PHOTO BY HENRY CARTER FOR WIKIMEDIA COMMONS

Treating Tragedy: Reflections on the Syrian Refugee Crisis

BY FAYEZ GHAZI, BIOLOGY, 2020

DESIGN BY ANNIE LEE, DESIGN, 2019

"When you get home, lie down on your bed…" The doctor paused, noticing the change in his patient's facial expression. I assumed it ended at dirt floors, lack of heat, water scarcity, and limited electricity, but I was wrong. The Syrians living in the Zaatari refugee camp didn't even have beds. There was an awkward pause before the doctor began to modify his prescribed exercise so that it can be done on the ground. It was the first day of my weeklong medical mission with the Syrian American Medical Society in Jordan, and my first time at any refugee camp.

The sadness was clear in the eyes of all the adults we treated. Occasionally, when the doctor I was assisting stepped out, some patients would confide memories of their past war-free life in me to pass the time. I noticed that only then did light return to their lifeless eyes. Nobody wanted to be a refugee, they had no choice. It angers me how only an extremely small minority of fleeing Syrians are able to resettle in another country and get access to proper amenities. The rest are forced to live miserably in what very much resembles concentration camps, patiently waiting for NGO's like SAMS to visit and provide them with basic medical care.

On that first day at the Zaatari refugee camp, I was assigned to a Neurologist. We saw forty patients in only six hours of allotted time, most of which suffered from similar symptoms caused by the cold. We treated so many symptoms that could have easily been avoided if the people had heat. Not everything was heartbreaking however. At the end of the day, I was able to play a small-sided game of soccer with some of the children. Their ignorance allowed them to laugh contagiously, as any child should.

Throughout the week, everyday held different experiences. I assisted internal medicine specialists, pediatricians, dermatologists, interventional cardiologists, and oncologists. I witnessed faces filled with uncertainty. I looked into eyes that have seen too much, shook scarred and stained hands, comforted sobbing mothers and fearful sons. It wasn't easy, but I have no right to complain. None of us do.

The mission, although emotionally taxing, was highly successful. Between four and five thousand patients were treated by the team. Additionally, the cardiologists performed seventy-nine critical cardiac catheterizations, the ophthalmologists removed fifty-one cataracts, the dentists conducted twenty-two pediatric surgeries, and the cardiothoracic surgeon performed three live-saving open-heart surgeries. That being said, these doctors did more than just treat wounds and sickness. The SAMS physicians gave the refugees hope, something they may have lost as the years passed.

My trip to Jordan was life changing to say the least. I was inspired by everyone I met and the experience solidified my goal of becoming a doctor even further. Visiting the camps also had me thinking: what can I, the average American, do to help? I believe our first step is to begin by supporting NGOs like SAMS. It's also important to protest the recent refugee ban signed by the President because compassion and security are not mutually exclusive. Countries like Lebanon and Jordan, who posses extremely limited resources, are taking in millions of refugees while powerhouses like the United States watch. It's time we began taking on some of our responsibilities as the greatest nation on earth and provided aid to our potential.

PHOTO BY NICOLAS RAYMOND

THE WONDERS BEHIND SPIDER SILK

BY IRENE OK, MOLECULAR BIOLOGY, 2020

DESIGN BY CIARA SELDERS, BEHAVIORAL NEUROSCIENCE, 2020

What usually comes into your mind when you think of spiders? Hairy long legs? Its multiple eyes? Charlotte's Web?

While many people associate spiders with fear and harm, spiders in fact provide humans with a great medical tool that is able to bring regeneration to a new level. This remarkable tool is spider silk, which spiders use for various purposes such as catching prey and protecting their eggs. Before transforming into a solid thread, the silk is liquid protein produced by spider glands. Spiders have the ability to transform the liquid protein into solid thread by physically pulling the silk through their spinnerets, its silk-spinning organ. The silk is composed of connected protein crystals, which gives it a strong structure of natural fiber. Due to its tenacious strength and elasticity, spider silk provides a promising therapy for both medical treatments and innovations.

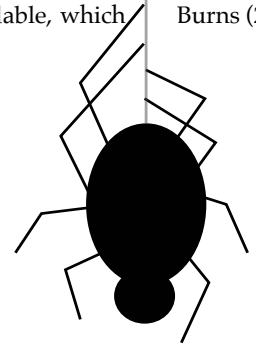
> "Due to its tenacious strength and elasticity, spider silk provides a promising therapy for both medical treatments and innovations."

The idea of using spider silk to create medical products is not a novel concept. This mechanism has been used for wound cover since the times of Greeks and Romans. They have used this technique to cover the wounds of soldiers to clot the bleeding. Fortunately, it was as simple as disinfecting the wound with antisepsis from nature and wrapping it around with silk. Not only is the silk firm and elastic enough to protect a wound, but also is composed of protein with an antiseptic property. The sticky, chemical coating on the silk has the ability to protect the web from bacterial attack. Moreover, spider silk is both biocompatible and biodegradable, which means the human body does not reject the silk as a foreign substance and dissolves as the wound closes. This shows less infections and more effectiveness.
Unfortunately, scientists are unable to use silk produced from real spiders because of Rather than using spider silk from actual spiders, scientists from University of Nottingham have recently discovered ways to produce synthetic, antibiotic spider silk. By using host organisms such as E. coli, they were able to produce man-made silk that has the same properties and effects as the silk from real spiders. Spider genes were inserted into E. coli and E. coli was able to express this gene and produce spider- silk protein. The synthetic material was then covered with antibiotic levofloxacin, a drug used for treating bacterial infections and wounds. These scientists revealed that the synthetic spider silk is not only able to regenerate tissue growth, but also release antibiotics that would aid in sterilizing wounds.

This doesn't end here. Spider silk can also potentially be used for bone and joint replacements due to its possible ability to replace and shape the damaged cartilage in the knee joints. Thanks to its thin, elastic structure and its strength, it could also eventually transform the surgeries and muscle repair. Furthermore, spider silk can not only be used for medical purposes, but also to create materials such as protective garments, helmets and air bags. It will be able to absorb the shocks and physical forces applied on these items better to reduce injuries.

The discovery of synthetic spider silk with an antibiotic effect has opened further possibilities for the future of both science and engineering. It is still a growing field with myriad of novel, potential treatments and innovations. Just as how a simple curiosity of spider silk led to a revolutionary discovery, where science takes us next is can be far more life changing. So the next time we see a spider, let us ponder on its phenomenal ability to provide biomaterial that transformed the humanity.

Burns (2009). DOI: 10.1016/j.burns.2009.12.001



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