ISSUE 30 Fall 2016

NU SCI

MICRO

>> Microfluidics give research a boost

>> Micro Steps to Mitigate Global Climate Change

>> Telling the Story of Organic Chemistry

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LETTER FROM THE PRESIDENT

As I am writing this letter, I am faced with the stark realization that in mere days my time at NU Sci will be complete. While the magazine has remained dear to my heart throughout the past twenty issues, it is difficult for me to eloquently explain how profoundly it has influenced me, both professionally and personally. NU Sci helped me uncover my passion for environmental science and science journalism. Now, I am incredibly thankful for having a platform to share these passions.

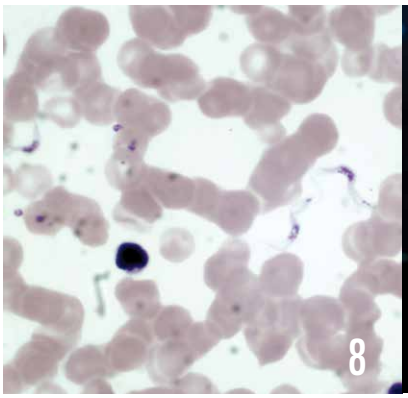
At a university where students are no strangers to change, science writing and NU Sci has remained consistent in my life. From the very beginning, I had great hopes for its future and its transformation was greater than I ever envisioned. When I first joined, the magazine was printed in black and white. As Treasurer, I marched with the magazine cofounders to the Office of the President to make our case for color print in the 21st century. Developing the marketing team also refreshed the magazine and enabled us to broaden our horizons, through promotional material, distribution events, increased online presence and much more.

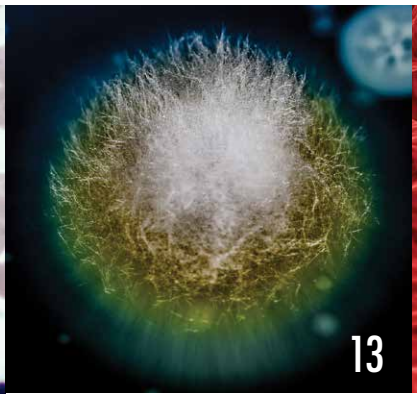
Science journalism has profound political, economic, and sociocultural implications, and it is imperative that the public be engaged in these key scientific debates. When developing innovative solutions to world issues like global climate change, it is essential that experts from various fields combine their knowledge. Scientists must collaborate with world leaders, academics and journalists to discuss and inform the public on these issues and their role.

I am enormously grateful and proud of our entire organization, including the e-board, editors, designers, marketing, and all of our writers. Issue 30 would not exist without their dedication and passion, and I wouldn't have wanted to work on it with any other group of people.

Cayman Somerville
President

COVER PHOTO BY SHUTTERSTOCK





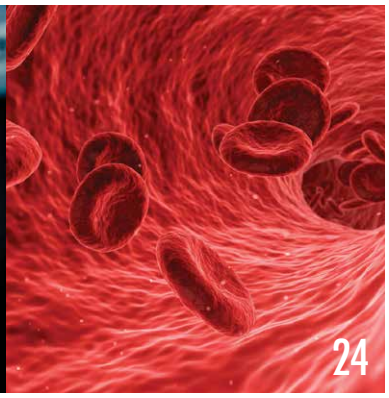
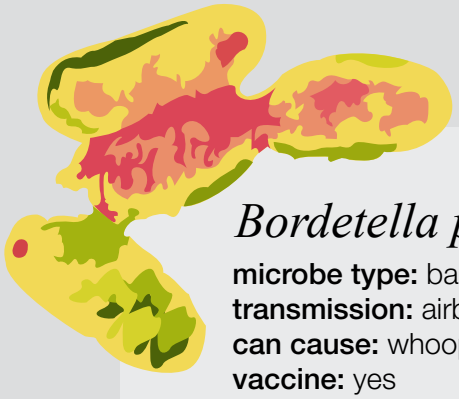


TABLE OF CONTENTS

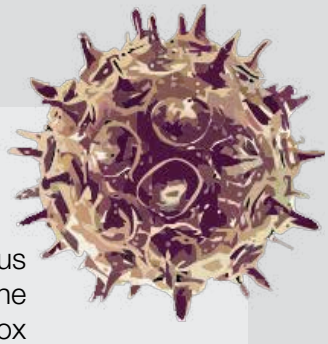
UNDER THE

pathogen
păth-ə-jən; *noun*
a bacterium, virus, or other microorganism that can cause disease.



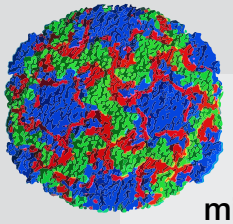
Bordetella pertussis

microbe type: bacterium
transmission: airborne
can cause: whooping cough
vaccine: yes



Varicella zoster

microbe type: virus
transmissiown: airborne
can cause: chicken pox
vaccine: yes



Rhinovirus

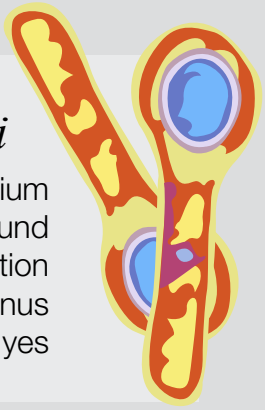
microbe type: virus
transmission: airborne, fomites
can cause: common cold
vaccine: no

Yersinia pestis

microbe type: bacterium
transmission: airborne, insect bite
can cause: plague
vaccine: yes (removed by FDA)

Myobacterium tuberculosis

microbe type: bacterium
transmission: airborne
can cause: tuberculosis
vaccine: yes (not recommended; limited effectiveness)



Clostridium tetani

microbe type: bacterium
transmission: wound contamination
can cause: tetanus
vaccine: yes

MICROSCOPE

the human microbiome

In 2012, a group of researchers at the National Institutes of Health undertook the daunting task of sequencing and defining the **normal** bacterial makeup of the human body.

microorganisms outnumber human cells

10 to 1

1 percent of bacteria are pathogenic

microorganisms make up

1-3%

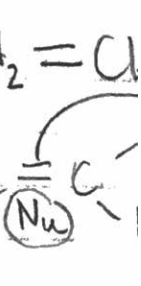
of body mass

in one human body...

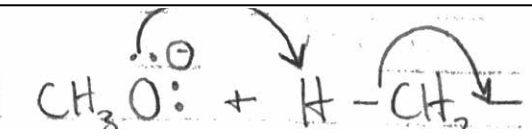
22,000 human protein-coding genes

8 MILLION bacterial protein-coding genes

BY ANNA LI, BEHAVIORAL NEUROSCIENCE, 2019



REACTIONS AND ROLEPLAY: TELLING THE STORY OF ORGANIC CHEMISTRY



BY GWENDOLYN SCHANKER, BIOLOGY AND JOURNALISM, 2018

DESIGN BY ANNIE LEE, DESIGN, 2019

Professor Oyindasola Oyelaran has spent her semester attempting to convince approximately 200 organic chemistry students that the subject many of them consider the bane of their existence is worth learning. She wears many hats – that of scientist, instructor, and fashionista – but throughout her years of teaching, she's adopted one very important role: that of narrator.

"It's a simple storyline that weaves through this subject," she says of organic chemistry, sometimes referred to as 'the chemistry of life.' "There's a few twists and turns along the way, but we can pretty much predict what the ending will be."

Those who hate math may take solace in the fact that organic chemistry involves almost no direct calculations. However, after spending months swimming in a sea of reactions, it's easy to get overwhelmed. Previous organic chemistry students tout the importance of study sessions and practice problems for good reason: there are several overarching themes that persist through what seems like such an obscure subject.

It's like "50 different versions of the same play," Oyelaran said. Nucleophile attacks electrophile. Acid reacts with base. Resonance delocalizes electron density and stabilizes the molecule. And so on.

In other words, while learning organic chemistry may feel like reading a number of dense, unconnected novels, it's actually more like a book series, where each step of the course builds upon the next. "It's the same story," Oyelaran said. "We're just changing the actors."

Heather Davis, senior chemical engineering major, former student of Oyelaran's, and current Organic Chemistry 1 peer tutor, says it's key for students to understand how the different books in the series are interconnected. "You have to put it all together," she said. "Even if you successfully memorize [everything], it's not going to work for you."

Because organic chemistry is so theoretical, it's also important to help students relate what they're learning to everyday life. Recently, Oyelaran started surveying her students at the beginning and end of the semester to see how much of the real-life applications they are taking in throughout the course.

"I want to know what exactly motivates students who are learning orgo," she said. "To do anything challenging, you have to be motivated. You have to feel like this is worth something and makes sense."

Brianna Hoang, a second-year pharmacy major who is currently taking Oyelaran's class, is fascinated by the overall concept of the course but sometimes gets caught up in the details.

"There's a whole science behind how we exist and who we are and what happens in life," she said. "It's crazy that the entire world is made up of all these reactions."

She says that it's helpful to have a professor who explains the reason behind what the molecules are doing, rather than just presenting what's happening. "There's so many rules and exceptions to those rules – it makes it hard to take it all in," Hoang said. "I ask the "why" question a lot."

Davis, who has been a tutor for three years, says she addresses the issue of relevance by personifying the molecules that seem so impersonal on the page, for example, by explaining to students that oxygen is "happy" with a negative charge while carbon is not.

"That's a problem with most classes, it's like, 'why are we doing this?'" she said. "You have to bring it down to earth and give some connection between the real world and how you're drawing this molecule, especially since you're drawing it a million times bigger than it actually is."

Hoang meets with Davis every week and says these peer tutor meetings are critical, if only because they help her slow down for an hour within such a fast-paced course.

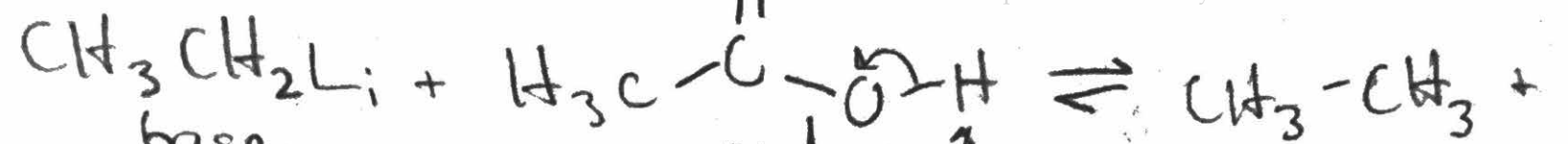
"I have it all in front of me but I might not know it," Hoang says of her notes, which she takes using an iPad and an Apple pencil that allow her to easily draw reactions in multiple colors. "A peer tutor adds time to digest and makes me sit down and work on it. They can fill in the holes that I might have."

Oyelaran says that learning organic chemistry closely parallels everyday life, since it forces students to confront unknown scenarios by drawing on past exams, problems, or notes. "The way we work through problems in everyday life is the same way we work through unknown pathways in organic chemistry," she said. "We take it step-by-step."

Davis finds slow and steady is the best approach to peer tutoring. "There's so many layers to the problem. Sometimes you have to go back to [general chemistry] basics," she said.

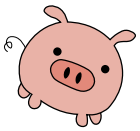
As intricate as the story of organic chemistry is, Hoang says the most rewarding part is reaching a happy ending. "My favorite part is how satisfying it is to know the end result," she said. "I love when I do a problem right and I know what's going on in the reaction."

Davis completely agrees. "When you're able to clear something up for someone, you see it on their face," she said. "It's such an accomplishment for both you and them."



Micropigs for Mega Discoveries... and Companionship





BY SAGE WESENBERG, BIOCHEMISTRY AND JOURNALISM, 2019

DESIGN BY ANNIE LEE, DESIGN, 2019

For years, cats and dogs have been the typical household pet. Cute, friendly, loving, and manageable, these small to mid-sized pets have been barking up the "man's best friend" tree for a reason. But what if you could have the excitement and intrigue of a more unique pet - say, a pig - without the large farm-like hassle that these large animals usually bring? Science may have your solution.

Researchers at Beijing Genomics Institute (BGI), the largest genomic organization in the world, with its headquarters in Shenzhen, China, have used gene editing to create micropigs as animal models for human genetic diseases. The scientific community often relies on many animal models like rats and mice because of their similarity to humans, affordability, and manageable size. But mice cannot give us everything needed to understand our human diseases. Pigs on the other hand, are genetically and physiologically much closer to humans and would be a more ideal animal model. However, because of their large size (the average farm pig can weigh over 220 pounds), pigs require more care, drugs, and equipment for an experiment, making them very costly animal models.

> "Pigs..., are genetically and physiologically much closer to humans and would be an ideal animal model."

In the last five years, gene editing techniques have been generating a lot of excitement within the scientific community. One of the most intriguing techniques uses the CRISPR/cas9 system. With the use of clustered regularly interspaced short palindromic repeats (CRISPR) as a spacer and the associated cas protein, this system allows for incredibly specific modifications to eukaryotic genes through insertions or deletions of segments of DNA. In 2014, BGI scientists published their success in modifying Bama miniature pigs through gene editing to disable growth hormones that prevent adult Bama pigs to reaching their full size. Unmodified, Bama pigs weigh anywhere from 35-50 kgs. With genetic control of their growth, the micropigs weigh only 15 kg, which is equivalent to a medium sized dog, about 33 lbs. But how is this possible?

With cells taken from the Bama pigs at their fetal stage, an enzyme called TALENs (transcription activator-like effector nucleases), was inserted to disable or knockout copies of the growth hormone receptor gene (GHR). As the fetal pigs develop, their cells can't receive a growth signal because of TALENs, leading to a stunted "micro" pig. These cells were cloned to produce reconstructed embryos that were transplanted back into sows. In order to create more micropigs after this initial process, male and female stunted pigs were bred together. Their offspring resulted in half micropigs, which more efficiently produces more micropigs, with less potential health problems than full cloning repetition.

As a result of the successful creation of micropigs to be used as more efficient animal models, research has been conducted on a variety of topics. Laron syndrome is a form of dwarfism due to a mutation in the human GHR gene that can be studied with the micropigs. They have also been used for research in stem cells and gut microbiota, as their gut bacteria can be easier to replace since they are smaller. Other research includes osteoporosis studies, a bone disease that causes major health problems - micropigs can act as a new animal model to study this because of its similarity to human pharmacokinetics, bone morphology, organ structure and function, and overall metabolics.

After presenting their cloning success in 2015, BGI noticed the excitement around their cute animal model, and realized they could make good pets. They now sell them as pets for about $1600 (US), and hope to soon be able to control coat color and patterns through further gene editing for even more personalized pets. This intrigues many scientists and ethicists worldwide. Harvard Medical School bioethicist Jeantine Lunshof explained to Nature that although gene edited pets may not be that different from those produced by traditional breeding techniques, just because it's more efficient doesn't mean it's a good idea. Ethicists argue that there is no need to stretch the limits of the genome just to please humans in pet aesthetics. And while it is unknown now, gene edited pigs are likely to have atypical medical problems that could become a large problem in the future. Additionally, pigs in general aren't usually indoor pets. Even if they're smaller, if they are kept inside a small home or apartment, they can become destructive in an attempt to dig in the dirt like most pigs do.

Right now, there is mostly excitement towards these cute, small animals. With the first big advancement in genetically altered pets, ethicists also worry that cats and dogs are next, which consumers will likely be much more concerned about. For now though, the science still needs to take priority. With these micropigs as pets, it is important that science can still progress in gene editing techniques and research for advancements in human diseases. In order to do so, guidelines and regulations should be put in place to ensure safety, ethics, and proper priorities for the future of gene editing.

Micro-sized Parasites on a Macro Scale

PHOTO BY VIVIEN ROLFE

Three very different parasitic organisms that affect millions of people

BY JORDYN HANOVER, BEHAVIORAL NEUROSCIENCE, 2017

DESIGN BY KRISTI BUI, COMPUTER SCIENCE, 2020

A parasite is an organism that infects and sustains life from a host, often to the detriment of the host. There are over 100 different types of parasites that can affect humans, according to the Center for Disease Control (CDC). Parasites can range from common infections like malaria or bedbugs to less common forms, such as neurocysticercosis or angiostrongyliasis. These parasites can have crippling effects on their hosts and often lead to a wide variety of symptoms based on the system that each parasite affects. Though millions of people are affected by parasites, several parasites are classified as neglected due to a lack of research and education.

schistosomiasis

Schistosomiasis is the second most common parasitic disease around the world, infecting hundreds of millions of people. The parasite infects humans through contact with water contaminated by freshwater snails. The worms enter the blood vessels as larvae and release thousands of eggs that are often transported out of the body. However, eggs that are not removed by the body typically attach to certain organs and cause major problems in that system.

Symptoms of the parasite depend on which type of worm infects the body. There are five different types of schistosomiasis, which often affect the urinary system - the liver and the kidneys. Oftentimes there is blood present in the urine in addition to abdominal pain, which can lead to complications like bladder cancer. In order to effectively diagnose the parasite, tests are done in excrement samples to detect the presence of blood. There is only one treatment currently available, which will alleviate some symptoms in the case of re-occurrence, but there is no other medication or vaccine available. Schistosomiasis can also be lethal - over 20 million people develop sometimes deadly complications such as bladder cancer, and approximately 200,000 people are killed each year due to the parasite.

neurocysticercosis

Neurocysticercosis is the most common central nervous system-based parasite, affecting over two million people around the globe, particularly in developing countries. These worms can grow to be over 20 feet long (longer than the average car!), and lay up to 60,000 eggs in the body of their host. Neurocysticercosis often develops from food contaminated with pork tapeworms, and has the most significant impact on the central nervous system. The most common symptom is epilepsy. Typical imaging studies are crucial in the diagnosis of neurocysticercosis and will show the progression of the parasite, as well as how far developed it is. There are multiple stages of the life of the parasite, each of which present differently on imaging scans. In addition to brain scans, cerebrospinal fluid can also be analyzed to detect the presence of the parasite at certain stages.

Treatments against neurocysticercosis vary depending on the development stage of the parasite, as well as the presentation of symptoms. If the parasite is still alive, treatment is based on which symptoms present – this usually includes anti-seizure and anti-cysticercal medication. In some indications surgery may be necessary to insert a shunt to avoid obstructions, or to remove all the cysts. While patients with uncomplicated cases are often able to live successfully with the parasite, some patients who develop parasite-related neurological complications become more difficult to treat and are more likely to suffer medicinal and surgical side effects.

angliostrongylus

Angiostrongylus is another parasite that causes problems in the central nervous system as well as the gastrointestinal tract. This parasite causes eosinophilic meningitis, which leads to a high level of a specific type of white blood cells in the cerebrospinal fluid. The worm's larvae can infect humans through undercooked snails, or contaminated water and vegetables, which reaches the central nervous system (CNS) through the blood. The presence of the larvae in undercooked snails has contributed to its growing presence as a public health issue. In the majority of cases the infection caused by the parasite will run its course without any side effects. When the parasite is present in higher numbers, symptoms persist which can include CNS damage.

Symptoms may begin as just nausea and headaches but can progress to irreparable damage depending on the severity and location of the parasite. Like neurocysticercosis, typical imaging studies are used to diagnose angiostrongylus but are often inconclusive. A lumbar puncture, or removal of fluid from the spine, is required in order to diagnose the meningitis. Additionally, there will be other eosinophil-related signals in CNS and cerebrospinal fluid testing which will indicate angiostrongylus.

Treatment for angiostrongylus is often a combination of anti-parasitics and anti-inflammatory medications to kill the worms. However, the worms release a variety of toxins as the medication kills them, so the drugs are given over a longer period of time to mediate the negative effects of the toxins. The anti-inflammatory medications are often used to mitigate the negative reaction to the dying parasites and to help with headache symptoms. Like neurocysticercosis, patients with uncomplicated cases where the number of parasites is lower tend to suffer less from debilitating complications.

Parasitic Puppeteers

A look into the behavior of parasite T. Gondii

BY ARIA ELAHI, BIOLOGY, 2017

DESIGN BY KRISTI BUI, COMPUTER SCIENCE, 2020

By the cruel hand of fate, parasites are tied to the progress and evolution of humanity in more ways than one can imagine. Recent discoveries regarding the protozoan parasite Toxoplasma gondii (T. Gondii) may shed some light on the matter.

T. Gondii is a parasite that can infect the brain of almost all mammals, causing the incredibly harmful disease of toxoplasmosis. In humans, it can cause acute symptoms ranging from swollen lymph nodes, headaches, fever, and fatigue to chronic symptoms such as urticaria and neural alterations. These symptoms can cause permanent physical and neurological damage that may be difficult if not impossible to treat. It begins with the infection of its definitive host, the feline. Definitive hosts are the main host that the parasite infects to survive and reproduce at the expense of its host. The parasite imbeds itself in the brain, liver, or muscle tissue of the host where it goes through a variety of stages in order to complete its reproduction cycle. Therefore, the goal of T. Gondii is to reach its main host in whatever way possible. This introduces some very interesting ways that T. Gondii is able to manipulate its intermediate hosts in order to reach its main host.

> “ T. Gondii is unique in that it can change the personality of its intermediate host in order to reach its main host.

This parasite is known to be able to change the behavior of rodents in order to make it easy for cats to hunt them down so that the parasite can infect the cat itself. Rodents typically have an aversion to cat urine so that they are repelled by the scent of their predators, however T. Gondii bends the designs of evolution to suit its own will. Rodents infected with the parasite not only have a decreased aversion to cat urine, but they are attracted to it, essentially giving themselves to their predators. T. Gondii is remarkable in that it can change the personality of its intermediate host in order to reach its main host.

So what happens if this behavior-altering parasite infects a human being?

T. Gondii is a widespread disease found everywhere in the world, the United States in particular has approximately 14% of its population infected by the age of 40 years. However, these rates vary across different parts of the world, where entire populations can be infected.

It was generally considered to be asymptomatic in humans except in extreme cases; however, recent evidence says otherwise. T. Gondii has the potential to create behavior differences in psychomotor performance and cause neurological disorders such as depression, suicide, but most importantly schizophrenia. A majority of the changes are very subtle and most people do not notice, thinking that it is a natural and inherent part of their personality when it may truly be a result of a T. Gondii infection. Studies have shown that men who are infected are more likely to be expedient, suspicious and jealous whereas the opposite pattern exists for women, as they may be more outgoing and conscientious.

However, there are some disturbing facts regarding the T. Gondii parasite. Women with the infection were 54% more likely to commit suicide compared to uninfected women and twice as likely to succeed. There appears to be a strong link between infection and suicide amongst women.

So how is T. Gondii able to manipulate the personality of its hosts and why?

According to a paper written by Physiologist Jaroslav Flegr of Charles University in Prague, “Toxoplasma manipulates the behavior of its animal host by increasing the concentration of dopamine and by changing levels of certain hormones.” Tweaking the delicate biological mechanisms that determine human behavior and decisions allows T.Gondii to determine the kind of people infected individuals become without them even knowing. However, there is still much confusion as to purpose of T.Gondii changing our behavior the way it does. Humans are a dead end host for T. Gondii, since they have no path to returning to its main host, the feline, once it has infected a human. Therefore, many scientists surmise that the effects were actually intended for its intermediate hosts and that the parasite is not aware that it is in a dead-end host. Because of this it may be possible that the personality changes caused by the T.Gondii is an unintended result, a biological glitch that is caused by the parasite being in the wrong host.

There is still much to learn about this astonishing parasite and the ways that it influences behavior and personality. This may mean that humanity may have to reevaluate its relationship with parasites and the possibility that they play bigger role in determining who we are individuals. One may even ask, are our decisions even truly our own?

Where does the person end and the parasite begin?

Schizophrenia Bulletin (2007). DOI:10.1093/schbul/sbl074

The Wonderfully Strange World of Animal Migration

BY LUCAS COHEN, MARINE BIOLOGY, 2019

DESIGN BY ANNIE LEE, DESIGN, 2019

Mass migrations of various organisms have long fascinated biologists around the world, and the phenomena that allow animals to travel enormous distances to and from specific locations have been the topic of countless academic publications. However, the means by which animals can detect the minute signals that guide them along their respective journeys are still the subject of widespread discussion.

In terms of raw biomass, the largest migration on the planet occurs every single day. It starts in the mesopelagic ocean: the layer of seawater extending between approximately 200 and 1,000 meters, where light from the surface begins to fade and the water becomes darker and increasingly cold. During the Second World War, the United States Navy discovered a region of the ocean – now referred to as the deep scattering layer (DSL) – that regularly distorted their sonar readings, such that there appeared to be a false ocean floor that ascended through the water column at night and fell back down during the day. It was ultimately determined that the DSL was caused by the collective movement of millions upon millions of tiny zooplankton engaging in a mass vertical migration. Diel vertical migration, as it's referred to in scientific literature, is likely a predator-avoidance strategy, whereby the zooplankton escape their photo-reliant predators by day and feed on their phytoplankton prey by night.

> "In terms of raw biomass, the largest migration on the planet occurs every single day."

The mechanism that drives this migration is the subject of ongoing research. Some suggest that the plankton's movement is an example of circadian rhythm: a sort of regular behavioral pattern characteristically associated with the day-night cycle. However, the body of evidence describing internal clocks in various zooplankton species is largely incomplete. An alternate theory states that the plankton follow the miniscule vibrations generated by their prey near the water's surface – a theory that follows an apparent trend in the study of animal migrations: that is, the ability of various species to home-in on infinitesimally weak cues from the surrounding environment.

Some animals, for example, pose the unique capacity to sense the earth's magnetic field. This magnetoreception is comparatively common in marine organisms – like, for example, the loggerhead sea turtle (Caretta caretta), of which both young and adults are able to distinguish between regional magnetic fields. Thus, magnetoreception is thought to be the principal means through which loggerheads maintain their regular migratory routes even in the mystifying expanse of the open ocean. The spiny lobster uses magnetoreception to consistently return to the same den after regular foraging excursions. Interestingly, the lobster does so without other cues like environmental landmarks, making it a "true" navigator.

Marine organisms are not the only creatures to have evolved magnetoreception, however; many species of migratory birds also make use of this peculiar sense. The European robin (Erithacus rubecula), for example, makes use of the earth's magnetic field during its migrations. It is vitally important to recognize that magnetoreception, however apparently miraculous, isn't a matter of science fiction – it's a measurable, explainable biological and biochemical phenomenon. In other words, there must exist within these organisms the necessary molecular machinery that would ultimately allow them to pick up the ostensibly faint signal given off by earth's magnetic field. Scientists are working to uncover the inner workings of these biochemical engines, but our understanding of magnetoreception is still incomplete.

Enter, again, the European robin. This species was once at the center of exciting research at the intersection of biology and, confusingly, quantum physics. Interestingly, the robin's magnetoreceptive abilities are conditional; in order to detect the minute signal given off by the earth's magnetic field, the robin requires a small amount of light. This particular observation led researchers in search of a photosensitive biochemical molecule present in organisms with magnetoreception – and, eventually, they found it: cryptochrome, a pigment protein found in the robin's eye.

As with most things involving quantum physics, it gets complicated. The proposed mechanism for crytochrome-based mechanoreception in the robin is as follows: some molecules within the cryptochrome protein complex generate free radicals – unpaired electrons within an atom's outermost shell – when met with energetic photons. In short, this empty spot is filled by an electron that originates from a pair of quantum entangled electrons from tryptophan, an amino acid (also within the cryptochrome complex). Quantum entanglement is especially tricky. In essence, the entangled electrons are one and the same; their quantum states are largely indistinguishable. The new electron remains entangled with its partner electron in the tryptophan molecule, creating a convoluted state in which the electrons possess multiple "spins" at the same time – a sort of quantum superposition. This makes the cryptochrome-based reactions in the bird's eye especially responsive to changes in the bird's physical direction, resulting in altered proportions of the associated reaction products and therefore – mysteriously – granting the bird mechanoreception.

The study of animal migrations has led researchers to delve deep into the rudimentary mechanisms that allow organisms to detect microscopic environmental cues like that of the earth's magnetic field. Research is being continually conducted into this fundamentally strange world.

In the Middle of the Ocean

BY KATIE HUDSON, MARINE BIOLOGY, 2017

DESIGN BY KYRA PERZ, CHEMISTRY, 2020

PHOTO BY KATIE HUDSON

At the top of a lighthouse, most of my view is occupied by blue. The thin island of Bermuda is stretched out below, and white roofs dot the green landscape. Although the island itself is peaceful, the environments that thrive in and around the shallow lagoon formed by the Bermuda platform, like many marine environments across the planet, are changing rapidly.

I have been in Bermuda since the end of August as a participant in the Research Experience for Undergraduates (REU) program at the Bermuda Institute of Ocean Sciences (BIOS). As part of this program, I am working in the Coral Reef Ecology and Optics Laboratory (CREOL) under Tim Noyes. Noyes is in charge of the lab's Marine Environmental Program (MEP), a long-term monitoring program was created by BIOS and the Bermudian government in response to an island-wide coral bleaching event in 2003. Both the government and BIOS recognized the need for a long-term monitoring program in order to understand the dynamics of the island's marine habitats. While the long-term monitoring programs ended in 2011, the MEP is ongoing, collecting observations on a variety of Bermuda's marine habitats on relatively shorter scales.

My job is to use the MEP long-term dataset to examine how coral reef diversity has changed over time. My role is to calculate four different diversity indices. Three of these indices – alpha, gamma, and beta – have been widely utilized in biodiversity studies since their derivation in the 1960s. Alpha and gamma diversity represent species richness, or the number of species in an area. Alpha diversity is representative of the number of species within a given sampling unit, which is defined as a geographical area such as a transect or quadrat. Gamma diversity represents the number of species present within a study area, or across multiple sampling units.

The third index - beta diversity - represents the similarity between two sampling units, rather than species richness. While this index is used most often in recent literature, there are a number of different ways to calculate it. As a result, one of my greatest challenges with this project has been determining how to carry out the beta diversity calculation.

The fourth diversity index is a new index that was recently described in 2014: zeta. Zeta diversity represents the number of species shared by multiple sampling units. As a result, it is similar to beta diversity, but is not limited by number of sampling units. Since its derivation, there have been no publications utilizing zeta diversity, so this project was a great opportunity for me to see how this new diversity index compares to the established indices.

I am also examining what factors are driving these changes on a variety of spatial and temporal scales. One of my goals is to use multivariate analysis to see how these factors, such as water temperature and level of coral disease, can contribute to changes in biodiversity over time.

While most of my time in the lab is spent at a computer analyzing large and complex datasets, I have also been able to go into the field to help my fellow undergraduate interns, who come from universities around the country, collect data for their respective projects. Their fieldwork includes everything from discovering new species of corals, examining bacterial communities in anoxic (oxygen-devoid) environments, and developing new techniques for analyzing plankton samples. While these tasks are unrelated to my project, I enjoy learning new sampling techniques, and of course, spending time on the water.

When we are not in the lab – or hiding from category three hurricanes – the other interns and I have been exploring the island of Bermuda: the pink sand beaches, lighthouses, and the capital city of Hamilton. Hamilton is an extremely diverse city, reflecting the demographics of its people. One of my favorite things about the island is watching the Gombay dancers. Gombay is a traditional Bermudian dance anchored in African, Caribbean, and Native American cultures that dates all the way back to the slave trade in Bermuda.

The eventual goal of my research project is to use the biodiversity calculations and the drivers of biodiversity to create a spatial model to predict changes in benthic biodiversity in Bermuda. Using ArcGIS, a popular data mapping program in the environmental sciences, biodiversity and its drivers can be mapped. These maps can then be used to create effective and efficient marine spatial plans. These spatial plans are extremely important in the creation of conservation legislation and marine protected areas (MPAs). The maps produced from this data will allow for the protection of areas that have conditions that promote diversity.

NU SCI EXPLAINS: PATIENT ASSISTANCE PROGRAMS

Pharmaceutical companies use assistance programs to incentivize drug purchase

BY JORDYN HANOVER, BEHAVIORAL NEUROSCIENCE, 2017
RAFI RAZZAQUE, ENVIRONMENTAL SCIENCE, 2019

DESIGN BY ANNIE LEE, DESIGN, 2019

With all the intensive debate over the uncontrolled, astronomical price hikes of prescription drugs, it might be comforting to know pharmaceutical companies are stepping in to slash their own costs - well, sort of. Certain companies offer a Patient (or Prescription) Assistance Program (PAP) to help cover the costs of a specific drug based on patient need, health care coverage, and income levels. Expensive drugs, such as Epipen, Abilify and Gardasil, are among the hundreds covered by these programs, designed to allow cost prohibitive name-brand drugs to reach the hands of needy patients.

Each individual drug a company deemed eligible for a patient assistance program receives its own set of conditions required in order for patients to participate. EpiPen, an allergen device that injects epinephrine into patients who suffer a severe allergic reaction, has been at the center of the recent drug pricing controversy, with particular regards to PAPs used by Mylan -- a pharmaceutical company with a variety of brand name and generic products based in Pennsylvania. When the program first launched this fall, a patient savings card of a $100 discount was available, as the product was not covered by many insurance plans. As the scandal of the price hikes progressed, Mylan upped the stakes by offering a new savings card that allows up to a $300 discount, or approximately half the price, for the product.

PAPs also have their limitations based on several factors determined by the company that owns the drug. Typically, household incomes must be less than a stipulated minimum, and in some cases, the drug may not be covered by a patient's health care plan. For example, the EpiPen savings card cannot be used under any federally funded health insurance plans, including Medicare and Medicaid, nor is it available to people who are uninsured. In addition, eligible patients must have a demonstrated need for the drug - in the form of a diagnosis or otherwise - by their doctor. In addition, some healthcare providers will not cover a drug that uses an assi tance program; there would be a heavy market bias towards name-brand drugs due to the extensive subsidizing.

In many cases (like EpiPen), people covered by government-funded programs are not allowed to use these coupons to save on their co-pays. The reasoning behind this is complex, but essentially comes down to health care provider versus patient cost. Take the following example: a co-pay for a month's supply of a drug costs over $100 at a typical pharmacy, but with a patient coupon the drug would likely not cost more than $20. However, a generic version of the same medication would cost the patient approximately the same amount of money - say $25. In this situation, the patient would be paying about the same amount of money, but the amount shelled out by the insurance company would be drastically different based on whether the patient purchased the branded or generic version of the drug. The baseline price for the generics is much lower initially, so while a patient may be inclined to purchase the branded drug with their coupon to cover portions of the co-pay, the insurance company would still have to pay the same amount. With a generic, the insurance company would be responsible for covering less of the drug's cost. Thus (in this example) a patient might pay $25 for a generic or $20 with their coupon for a branded drug, but the insurance company might pay $1500 for the branded version versus $200 for the generic.

Patient assistance programs give drug companies with name-brand products a fighting chance against aggressively government-subsidized generics. PAPs give the public a chance at obtaining hard-to-afford drugs that can make a lifetime of difference, and it also gives the private sector of drug development a fighting shot in the ever-changing market of the healthcare business. In this healthcare business, low-quality care is never an option, but perhaps low-cost care through a combination of insurer regulations and patient assistance programs might be a solution.

SHOWTIME FOR MICROBES

Photography and research from Scott Chimileski brings microbes into the spotlight

BY ADRIANNA GRAZIANO, BIOLOGY, 2019

DESIGN BY ANNA LI, BEHAVIORAL NEUROSCIENCE, 2019

Life began microscopically. Microbes are the reason for life on Earth, from the creation of the protective ozone layer, to the evolutionary origin of our mitochondria, and the production of some of our favorite foods. However, it's hard to understand or even conceive of these invisible creatures without some help. Scott Chimileski, a microbial scientist and imaging specialist at Harvard Medical School, brings life to the microbial story through his research, photography, and writing.

From the age of 15, Chimileski was inspired by his great uncle, Rene Pauli, to begin photography. He enjoyed photography and nature as a hobby, but went on to pursue undergraduate and doctoral degrees in genetics and genomics at the University of Connecticut. There, his research focused on gene transfer mechanisms and biofilm formation in haloarchaea. It wasn't until he noticed the day-to-day migration of a biofilm during his PhD research that both Chimileski's passion for photography and his commitment to microbial research converged.

By setting up a time-lapse incubator to observe the movement of haloarchaea communities on the biofilm, he came to make discoveries about complex social and collective microbial behaviors. After his PhD, Chimileski joined the Kolter Lab in the Microbiology and Immunobiology Department at Harvard Medical School in 2015 to begin his postdoctoral work.

Though he sees his primary role as a researcher, Chimileski is committed to creating a movement to inspire a national microbial presence by breaking through mainstream channels and communicating with the general public through writing and photography. This inspiration came after a visit to Harvard's Museum of Natural History (HMNH) in 2014, where he noticed only one small cartoon depiction of bacteria in the entire museum. He was surprised, thinking "the natural history of the Earth has always been and continues to be mostly microbial!" He began brainstorming ways to effectively teach the public about the positive and far-reaching impacts of microbes – soon he and Roberto Kolter proposed their ideas to the museum. Fast forward to now, and Chimileski, Kolter and a team including the museum directors and designers are preparing to open a Microbial Life exhibition at the HMNH in 2017. The exhibition will focus on microbial foods and include a real kitchen setup with live microbes to engage the public in a real life encounter with microbes to highlight their importance in daily life.

At the same time as the museum release, Chimileski and Kolter's nonfiction book, will be on bookshelves across the country. "Life at the Edge of Sight" begins in the Netherlands, following the man who began the field of microbiology and is acknowledged as the first person to ever see microbes: Antonie van Leeuwenhoek. By connecting narrative with science and including 200 images of original microbial photography, Chimileski hopes to communicate the biology of the unseen world to non-scientific audiences. Images featured in this book come from work in the laboratory, wild microbes found right in our homes and backyards, and "microbial science photography expeditions" to Yellowstone National Park, Great Salt Lake in Utah, and the White Cliffs of Dover in the UK. By highlighting microbes' natural pigments and structures in his images, Chimileski hopes to "act as a curator of the beauty of microbes that's already out there on Earth."

Chimileski's work is multifaceted as he takes on the combined role of researcher, photographer, and author. He strives to engage the public's interest in microbes as author Edward O. Wilson did for ants. Wilson's books connected ant behavior to similar social behaviors and hierarchies that humans engage in.

One thing is for sure: Chimileski's microbial work will continue to have an impact on both scientists and non-scientists for years to come. As he says, "Let's give microbes the spotlight in our Natural History museums."

For more information about Chimileski's research, projects, writing, and photography, visit http://www.scottchimileskiphotography.com.

PHOTO BY SCOTT CHIMILESKI

Micro Steps to Mitigate Global Climate Change

How you can make a difference

BY CAYMAN SOMERVILLE, ENVIRONMENTAL SCIENCE, 2016

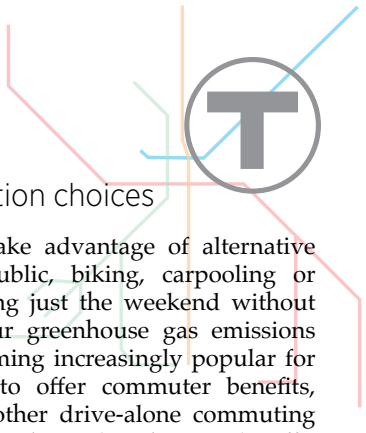
When the next President of the United States of America was announced to be Donald J. Trump, fear and devastation struck environmentalists around the world. Environmentalists, like Leonardo DiCaprio, urged the public to address his previous claim that climate change was a "hoax." Travesties in Mr. Trump's environmental policies include his pledge to withdraw the U.S. from the Paris climate treaty, revive the coal industry and increase oil and gas drilling. Furthermore, the President-Elect vows to demolish the Environmental Protection Agency (EPA) "in almost every form" and plans to appoint a well-known climate change denier, Myron Ebel, to lead the transition team. As we enter a new chapter in our nation's history, where the future of our climate policy and planet seems vague and the President does not prioritize critical mitigation efforts, it is more important now than ever for citizens to do their part to mitigate global climate change impacts.

1. Buy energy efficient products

When buying new light bulbs and products for your home, be sure to look for EPA's ENERGY STAR-qualified products. The EPA reports that these products could save you up to $11,000 on energy bills and reduce emissions by around 130,000 pounds - the equivalence of supplying electricity to 19,197 homes in one year. Furthermore, other benefits of ENERGY STAR lighting include warmer lighting, a 10 to 50 times longer lifetime, and both a energy and a heat reduction of 75 percent.

2. Monitor your energy use and conserve your consumption where you can

It has been reported that the average European consumes 50 percent less energy than his or her American counterpart. The EPA has a tool that enables you to make greenhouse gas emission estimates from your energy use. Known as the "Household Carbon Footprint Calculator," it allows homeowners and residents are able to identify ways to reduce their emissions and thus find cost savings.



3. Make wise transportation choices

Rather than driving a car, take advantage of alternative methods, such as taking public, biking, carpooling or working from home. Spending just the weekend without your car could decrease your greenhouse gas emissions by 2 tons per year. It is becoming increasingly popular for employers and universities to offer commuter benefits, which may compensate for other drive-alone commuting impacts, including expensive or limited parking and traffic congestion.

If you do choose to drive, reduce emissions and improve your fuel economy by reducing hard acceleration and stops, idling, and the weight of your vehicle (unload items in your trunk!). Additionally, keep up with maintenance and tire pressure, and utilize other features of your car, such as cruise control and two-wheel drive. When you are renting or purchasing a car, be sure to buy a clean, fuel-efficient, and low-greenhouse gas car

4. Be smart about home insulation

Taking measures to ensure your home is sealed and insulated can reduce your heating and cooling costs by up to 20 percent. By minimizing air leaks and adding more insulation to your attic, heat and cool air can remain trapped in during the winter and summer, respectively. Additionally, by upgrading your heating and cooling equipment to more efficient technology, utilizing a programmable thermostat and frequently changing your air filters, you can conserve energy and reduce environmental consequences.

5. Become a Locavore — eat local, sustainably sourced foods

A locavore is someone who supports sustainable, healthy food practices by eating locally grown foods. In addition to nutritional benefits, local growers tend to minimize chemical fertilizers and pesticides used on their crops. Traveling less for food alone reduces food packaging and CO2 emissions. Furthermore, a regional diet utilizes 17 times less oil and gas, in comparison to eating food shipped from the other side of the country. If you are not ready to become a vegetarian or vegan, you can contribute by purchasing produce from farmer's markets, checking labels or trying a delivery program from a Community Supported Agriculture (CSA).

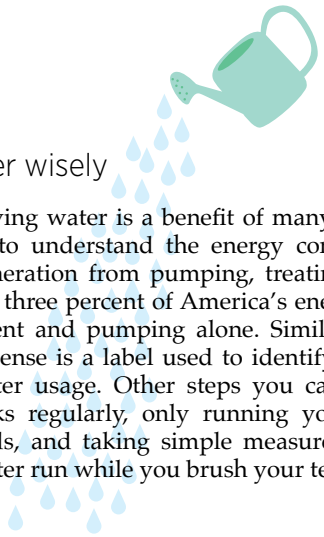
6. Eat less meat

By cutting meat out of your diet, you could save 162,486 gallons of water each year—enough water to ensure 445 people in water-scarce areas can survive. By cutting meat out of your diet, you could reduce your carbon footprint by more than two thirds. Furthermore the United Nations Food and Agriculture Organization (FAO) has estimated livestock production makes up 14.5 percent of global greenhouse gas emissions at the very least.

7. Reuse, reduce, recycle, and compost

It may sound cliché, but the biggest micro step you can take is to reduce the waste you generate. According to the EPA, the average American generates 4.4 pounds of waste per day, and combining all trash in the United States could fill up 63,000 garbage trucks each day. Unfortunately, less than a third of that trash is recycled or composted. To do your part you can start by making smarter shopping choices, reducing the amount of packaging you bring into your home. Additionally, purchase recyclable products and reuse and recycle whenever you can. Finally, by composting your yard waste, food waste, and other organic wastes, you can significantly decrease waste and the need to dispose it.

8. Use water wisely



While conserving water is a benefit of many other steps, it is important to understand the energy consumption and emissions generation from pumping, treating and heating water. In fact, three percent of America's energy is used for water treatment and pumping alone. Similar to ENERGY STAR, WaterSense is a label used to identify products that minimize water usage. Other steps you can take include repairing leaks regularly, only running your dishwasher with full loads, and taking simple measures, such as not letting the water run while you brush your teeth.

9. Plant trees

Many environmental organizations have begun reforestation programs, monitoring the immediate benefits of restoring rich ecosystems. By donating small amounts, a tree can be planted in dedication to anyone. In addition to preserving endangered species, tree planting is a simple action everyone can take to reduce carbon dioxide. You can plant trees around your home, in your local community, or in our national forests.

10. Spread the word

Speak up! Spread the word to your friends, colleagues, schools, and family members that the future of our planet is in their hands. By sharing the benefits of taking energy efficient measures, your peers can also take these small steps to help out. There are numerous student groups on Northeastern University's campus who give students a platform to use their voice about environmental issues. You can join Husky Energy Action Team (HEAT) and collaborate with Northeastern University administration and staff on establishing environmental sustainability and carbon neutral initiatives around campus. In TERRA, another club focused on Earth, students meet to promote environmental topics and plan related local events. There are numerous groups who are working together towards a better a future for our planet.

DESIGN BY ANNA LI, BEHAVIORAL NEUROSCIENCE, 2019

OPINION

TRUMP'S FIRST HUNDRED AND THE ENVIRONMENT

BY RAFI RAZZAQUE, ENVIRONMENTAL SCIENCE, 2019

DESIGN BY ANNIE LEE, DESIGN, 2019

President-elect Donald Trump's stunning upset in the 2016 presidential election has many questioning the country's future. Trump's presidential campaign has polarized the country, and many unanswered questions remain, especially regarding Trump's divisive comments on science and the environment.

In NU Sci Issue 29, myself and club president Cayman Somerville described Trump's stance on an array of science topics, including fossil fuels and environment. Following Trump's tumultuous victory, I've re-examined Trump's 100-day plan, recent comments, and his chosen cabinet members to better understand how the environment will fare under a Trump presidency.

Donald Trump's now-infamous tweet on climate change being "a concept...created by and for the Chinese to make US manufacturing uncompetitive" has been extensively retweeted and criticized, despite Trump's insistence he claimed to believe otherwise during the first presidential debate. Trump's skeptical view of the issue, along with a Republican-controlled House and Senate, has many fearing that climate change mitigation measures set down by the Obama administration will be overlooked, defunded, or removed.

During the First Hundred Days speech, Donald Trump specifically targeted "lift[ing] the Obama-Clinton roadblocks" towards "vital energy infrastructure projects," naming the Keystone XL pipeline as one example. He hopes to circumnavigate the Obama administration blockade of the Keystone XL and facilitate completion of the project.

Trump's appointment of lobbyist Myron Ebell--a known climate change skeptic--to head his environmental transition team has stimulated widespread concern among environmentalists. Ebell has worked with the Competitive Enterprise Institute (CEI), a libertarian advocacy group, before his appointment to the Trump administration. During Ebell's term at the helm CEI, the organization accepted tens of millions of dollars in funding from petroleum companies and anti-climate change think tanks. Ebell takes a cynical view of the environmental movement, stating that environmentalists believe, "the use of human power is always bad; everything we do to nature is bad." He also opposes the Clean Energy Power Plan and Paris Agreement, both of which President Obama signed during his term.

Ebell will be tasked with Trump's goal of gutting the Environmental Protection Agency (EPA), leaving "only tidbits left...but most out of it." This allows Trump to achieve his campaign promise of tapping into $50 trillion worth of fossil fuel reserves, which will stimulate the coal industry. This will most likely undo previous efforts by the Obama Administration, including the Clean Energy Plan and Paris Climate Agreement, both of which Trump deems "unconstitutional." Trump has pledged to withdraw from the Paris Agreement, which commits its 193 signatories to reduce greenhouse gas emissions by up to 80 percent by 2050, in order to limit the increase in atmospheric temperature to 1.5°C above pre-industrial levels.

Trump plans to make environmental policy less of an international affair. In his 100-day plan, Trump discussed "cancel[ing] billions in payments to United Nations (UN) climate change programs." Presumably, he is referring to the $10 million a year the US gives to the UN Framework Convention on Climate Change (UNFCCC), as well as its future participation in accords like the Paris Agreement.

Trump's plan has other implications that could tangentially affect the environment, including a promise to reduce two existing federal regulations for every new regulation proposed, potentially leaving climate regulations vulnerable to elimination. President-elect Trump will also have to nominate at least one, if not multiple, Supreme Court justices to fill vacancies in the court. If, as expected, Trump appoints historically conservative figures, this could pose a risk to present and future climate agreements and coal use.

It's not all doom and gloom for the environment under Trump's presidency, though. Trump has already begun to retract some of his harshest campaign lines, including his position on completely replacing the "expensive...fraud" that is Obamacare. This suggests he may also compromise on environmental regulations. Trump has also encouraged ethanol production as a feasible form of biofuel in light of our heavy use of fossil fuels, and has promised that if the U.S. withdraws from sending money to the UNFCCC, he intends to spend the money "to fix America's water and environmental infrastructure," an undeniably important issue given the recent Flint water crisis. Trump has promised he is "a great believer in all kinds of energy," suggesting that clean energy use may continue to increase under his presidency.

A primary risk of the Trump presidency is decreased environmental regulation, leaving regulation up to individual businesses. This concern, combined with Trump naming a known climate denier as a head of his cabinet, has made environmental groups fearful of what could happen as our atmospheric carbon levels continue to increase. It will be up to Trump to stick to his promise that he believes in alternative energy and the improvement of American environmental infrastructure. As the people under Trump's presidency, it's our right to push and remind him to stick to these promises.

Exonerating 'Patient Zero'

A look into how a patient undeservedly became the scapegoat for the HIV epidemic

BY RACHEL SON, CELLULAR & MOLECULAR BIOLOGY, 2020

DESIGN BY KRISTI BUI, COMPUTER SCIENCE, 2020

Although invisible to the naked eye, viruses can wreak havoc and devastation on humans in the right (or rather, wrong) circumstances. These microscopic materials are a perfect example of incredible power in something very small. Arguably one of the most infamous viruses, human immunodeficiency virus (HIV), is an incurable sexually transmitted disease that has spread all over the world.

For years, popular culture has blamed the introduction of HIV to the United States on a promiscuous French-Canadian flight attendant referred to as "Patient Zero" sometime before 1982. A book titled And the Band Played On: Politics, People, and the AIDS Epidemic was published in 1987 and heavily implied that Patient Zero's actions led to the spread of HIV into the United States. Patient Zero became the scapegoat for the spread of a terrible and complex immunodeficiency that he was unknowingly transmitting to all of his sexual partners. At first, the immunodeficiency was associated with homosexual men so strongly that it was even called Gay-Related Immune Deficiency and contributed to an increased negative stigma for homosexual men.

> "The data suggest that HIV actually arrived in the U.S. from the Caribbean and spread to New York City in about 1970.

The identification of HIV-1 group M subtype B, the strain of HIV found in patients (including Patient Zero) within the United States in the 1980s, was a significant event in the early history of HIV in North America.

Unfortunately, the truth about this virus's beginning is much more complex than the story of Patient Zero. Despite its infamy, however, little genomic information about the initial rise of HIV-1 group M subtype B in North America existed – until recently.

Researchers from universities and disease prevention organizations in the U.S., the UK, and Belgium have collaborated to explore the introduction and spread of HIV in North America. They sequenced the genomes of the HIV virus sampled from homosexual men in New York City and San Francisco during the late 1970s and used Bayesian statistics and phylogenetic analyses (calculated likelihood of events and constructed and analyzed evolutionary trees) to examine the evolutionary relationships between the collected samples of HIV.

The data suggest that HIV actually arrived in the U.S. from the Caribbean and spread to New York City in about 1970. Growth models drawn from the available data also suggest an incredibly rapid growth of the HIV epidemic in both the United States and the Caribbean. Cases of HIV doubled every 0.86 years in the U.S. and every 1.12 years in the Caribbean. No biological evidence suggested that Patient Zero is to blame for the spread of HIV in the United States; in fact, the data support the hypothesis that HIV entered the country years before Patient Zero allegedly transmitted HIV to his sexual partners. Phylogenetic analyses also suggest that the genome of HIV-1 sampled from Patient Zero was not a basal strain for other HIV strains collected from other patients and so Patient Zero was not the originator of the American HIV epidemic. The data even suggest that many of the 1978 San Francisco HIV-1 infections can be traced to a single HIV-positive person in New York City in 1976, who could not be Patient Zero.

So why did a French-Canadian flight attendant become the scapegoat for an entire nation's HIV epidemic? The answer lies in a statistics mistake. Patient Zero was a member of a cluster of patients, all homosexual men with the mysterious immunodeficiency that would later be identified as HIV and who were connected by a network of sexual partners. This cluster of patients was a key piece of evidence that HIV was a sexually transmitted disease. Patient Zero also provided investigators from the Centers of Disease Control with plasma samples and the names of almost 10% of his sexual partners. In comparison, other patients within this important cluster were only able to share a few names with the investigators.

Through his willingness to help investigators determine as much information as possible about this newly discovered disease, Patient Zero may have inadvertently become misattributed as the cause of the initial spread of HIV in North America due to a phenomenon called ascertainment bias - the information he volunteered most likely resulted in diagrams of the patient cluster that suggested Patient Zero was at the center of the spread of HIV within the patient cluster.

The data these researchers gathered and examined has revealed novel insights into the early history of HIV in North America. It may be impossible to ever fully uncover the true "Patient Zero" who first introduced HIV into the United States. Still, the researchers who constructed phylogenetic trees and conducted statistical analyses on decades-old preserved samples were able to rule out a false story and open up the possibility of learning more about the true early North American history of HIV.

SCIENCE OF THE FUTURE:

MICRO HUMANS CULTIVATED FOR DRUG TESTING AND PERSONALIZED MEDICINE

BY WHITNEY KUWAMOTO, BEHAVIORAL NEUROSCIENCE, 2020

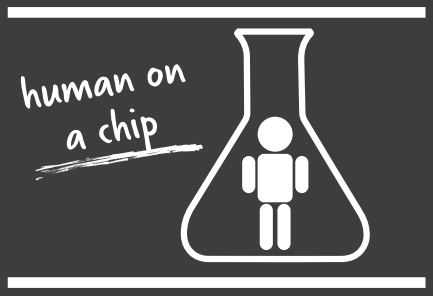
DESIGN BY JULIETTE PAIGE, MECHANICAL ENGINEERING, 2020

Imagine a human no bigger than the size of a USB chip, fully functional in sustaining life, with organs the size of grains of rice. While this "human" is not a conscious, talking being, its body still emulates a typical human's biological operations, allowing for non-invasive, in vivo drug tests on human organs. Sounds impossible, doesn't it?

Over the past decade, miraculous strides in the field of biotechnology have allowed individual human organs such as the lung, stomach and heart to be grown on a plastic chip. Though these achievements allow researchers to observe drugs' direct effects on specific organs in vitro, they do not allow them to see how the rest of the body's systems are affected by the same drug. Contrarily, animal models provide a complete biological system to observe a drug's effect, but they have one glaring issue: animals are not human. Using animal models for drug testing creates unpredictable results, making it impossible to determine the safety risks of newly-developed drugs in humans.

Millions of dollars are funneled into drug development, yet nearly 90 percent of these new drugs are rejected from reaching the mass market due to safety concerns from the drugs' side effects. This extremely untimely and expensive issue in the advancement of drug development poses a huge setback in releasing new, possibly more efficient drugs. However, researchers at the company Tissuse, a German company dedicated to emulating human biology, have the solution: drug testing on a micro human-on-chip.

Tissuse has successfully developed a 2-organ and 4-organ microchip; however, a 10-organ microchip in which each organoid – or mini human organ – interacts as a system, is expected to be released in 2017. These chips, constructed atop glass microscope slides, consist of four layers: an adapter plate, nutrition plate, organ plate, and sensor plate. Each chip operates through a system of interconnected microfluidic networks to simulate the interaction of organs as they function in the body. A technique called micro-scale Particle Image Velocimetry (μPIV) is then used to measure a drug's effect on each organ. By injecting tracers, particles negligible in size but easily identifiable with a digital camera, into the chip's network, researchers can track the flow of substances through the chip. This allows researchers to compare pictures from before and after a drug is administered to observe each drug's overall effectiveness and its effects on the health of each organ. If more tracers are present in one organ than in others, the drug is more effective in that specific organ.



To conduct a drug test within the organ chip, an experimental drug is injected into one of the microfluidic networks atop the organ plate through the adapter plate, where it is then circulated through the rest of the "body's" organs. Next, the organ chip is assembled, and the organ plate is placed on the sensor plate, and the adapter and nutrition plates are placed on top of the former stacked plates. By adding the sensor plate, the organ chip allows for quick screening of where the experimental drug has traveled and how it has affected each organ on the chip. The adapter plate facilitates the injection of each experimental drug into specific networks. Depending on how each drug needs to be administered, different sites on the adapter plate can serve of different methods of drug ingestion (i.e. orally, nasally, topically, etc.).

In the coming year, the development of a "Human on a Chip" (HoC) is expected to revolutionize human drug testing, eventually rendering animal models obsolete. By culturing organoids, researchers can set up closed systems that closely resemble a living human body. The increased use of induced pluripotent stem cells (iPSC), adult cells reduced back to pluripotent stem cells, in medicine allows for the possibility of culturing organoids using individual patients' cells. Moreover, this can enable drug companies to see how a drug's direct effect organs in various diseased states, and if different stages of diseases affect a drug's effectiveness. The HoC opens an infinite amount of possibilities for the advancements of both drug development and personalized medicine while providing a cheaper, more accurate alternative to drug testing on animals.

Researchers at Tissuse aren't the only ones developing a HoC for drug testing; the Wyss Institute for Biologically Inspired Engineering, a research institute at Harvard University, is also manufacturing their own HoC model. By utilizing transparent, flexible platforms, Wyss researchers create "Organs on a chip" (OCs), microenvironments that emulate the conditions necessary for individual human organs to survive. To create their HoC model, Wyss researchers connect several microfluidic circuits, using one OC to represent each organ, to mimic organ systems rather than having the entire human body on a single chip. The transparency of each chip makes any effect a drug has clearly visible within each OC.

The human body, a product of millenniums of evolution, particular in design, and unique in its functionality, is a creation of nature that cannot be paralleled by man. Its incredible efficiency of incorporating numerous factors to perform one simple function is an action that only living bodies can execute. These bodies, complex machines of interconnected systems, have been copiously studied and compared to those of model organisms, but the intricacies of human organ systems have yet to be accurately reproduced in laboratory conditions. Though the HoC model is still just a technology of the future, it will soon provide an ethical, unprecedented method for direct drug testing on human organs.

Unscrambling the Mystery Behind INFERTILITY: The Eggert Solution

BY STEPHANIE WASIUK, BIOLOGY, 2017

DESIGN BY JULIETTE PAIGE, MECHANICAL ENGINEERING, 2020

Meet Tanner Eggert. He is a second year biochemistry major with minors in math and physics. He probably has one of the most appropriate last names for working in the LAIR, the Northeastern Laboratory for Aging and Infertility Research. This lab, run by Professor Jonathan Tilly, a University Distinguished Professor and chair of the Biology Department, and Assistant Professor Dori Woods focuses on women's reproductive issues and is hoping to re-define infertility solutions.

When Eggert was attending a presentation given by Professor Tilly during Parent and Family Weekend in 2015, he discovered that the research being done in the LAIR hit close to home. Eggert's aunt had been living with a disease that rendered her sterile. She tried in vitro fertilization (IVF) multiple times, but unfortunately her efforts were fruitless. Eggert was later given the opportunity to work with Professor Tilly and Professor Woods so that he could have a hand in discovering a solution not only for his aunt, but for affected women all over the world.

Tanner works under PhD student Julie MacDonald and studies oocytes, which are immature eggs in a female's body. These oocytes will eventually become mature ova, which can then be fertilized to form a zygote. Previously, it was believed that women were born with a fixed number of oocytes and that once they ran out, they would no longer be able to have children. But the research conducted in the LAIR is challenging that belief.

Oogonial stem cells (OSCs), the precursors of oocytes, are isolated from the cortex of ovaries – in most cases, mouse ovaries; these OSCs are then grown in vitro, meaning in a dish. What is curious is that some will spontaneously differentiate – that is, reach their mature form – yet others will not. So if these cells are in the exact same environment under the same conditions, what makes some become oocytes while others remain undifferentiated?

The LAIR believes the answer lies within the cells' genes, specifically the stra8 gene, which is a germline marker. In mice, this gene is responsible for regulating spermatogenesis, or the production of sperm, and oogenesis, the production of eggs, but it is unknown if it has the same function in human cells.

In some cases, certain OSCs will not differentiate when stationary, but if they are moved they will develop into oocytes. Eggert is maintaining cells that have undergone many rounds of stretching – and no, this isn't the latest fad in cell aerobics. A complex machine is used to stretch single cells using a vacuum, which rearranges the actin filaments of the cytoskeleton.

The rearrangement of actin filaments is relevant to mechanotransduction studies, which analyze the response of a cell to some sort of physical stress. When the extracellular matrix (ECM), a network of proteins on the outside membrane of a cell, is altered, actin filaments in the cytoskeleton are shifted via their connection to the ECM through integrin proteins. This acts as a stimulus to the cell and travels through to the nucleus, which in turn can affect gene expression. By stretching these cells, the LAIR team can look at stra8 and other genes and determine whether or not they play a role in differentiation.

Another focus of the lab is on the mitochondria of oocytes. When the mitochondria are too old, the oocytes are unable to produce enough energy to function and they essentially go bad. Research from the LAIR shows that if the mitochondria from OSCs are transferred into oocytes, it acts as a

fountain of youth, making them more functional.

The LAIR's ideal end goal is two-fold: provide research to develop a drug that can address the issue of mitochondrial degradation and a drug that would cause OSCs to differentiate on command.

The research being done by Eggert and the rest of the LAIR could have major implications for reproductive sciences and society in general. The techniques being studied could change the lives of women with reproductive issues and could replace IVF, which is a very expensive procedure for one that, in many cases, has no guarantee of success.

Over the past year, Tanner has enjoyed being part of a lab that is working to solve such a major problem and is excited to be part of such wground-breaking research. In the future, he looks forward to gaining different experiences in other fields, such as physics and chemistry.

QUANTUM SPOOKS

BY JAMESON O'REILLY, PHYSICS AND MATH, 2019

DESIGN BY CATU BERRETTA, COMPUTER SCIENCE, 2020

The world can be a scary place, especially when not well understood. Uncertainty strikes at the heart of the security that all humans crave, the ability to rest easy for even a moment without having to fight for your right to survive. To reach any kind of peace, these holes must be dealt with somehow.

Filling in gaps illuminates our universe. The steady march of science has built a patchwork quilt of theoretical frameworks to explain the vast majority of phenomena that we observe, but many gaps persist. Some concepts, like dark matter, have no clear explanation yet, while others are only valid at scales that boggle the human mind. Nobody can count infinite sheep to fall asleep, even in the worst cases of insomnia; it is simply impossible to imagine, impossible to hold in your mind all at once. At the same time, nobody can truly comprehend the infinitesimal size of an atom.

> "Every thought, choice, and action can only be driven by previous experiences and knowledge.

Every thought, choice, and action can only be driven by previous experiences and knowledge. If anything, the problems with absorbing the implications of the infinite and the infinitesimal are just particular examples of our larger difficulty with internalizing things we have not personally experienced. Quantum mechanics is another, related example.

For one, quantum mechanics is only really relevant at unimaginably small scales. For another, its key tenets fly in the face of everything that we understand based on everyday experience. This is what makes it unintuitive and sometimes intimidating for people to learn. It seems like it cannot possibly be real, or at least that it is only accessible to some select group of people. When somebody says that nobody understands quantum mechanics, they are probably referring to the fact that it makes no sense to people who live their life at a relatively macroscopic scale. The most famous example of this is probably the concept of wave functions immortalized by Schrodinger's Cat. This cat was originally a thought experiment by one of the preeminent physicists of the time trying to disprove quantum mechanics. Schrodinger felt that a cat being neither dead nor alive, but a superposition of the two, until observed was preposterous. Eventually, he came around but his thought experiment lives on as a perfect example of the incompatibility between common sense and quantum mechanics.

That being said, there are many people who effectively use quantum mechanics every day. Many of the inventions that power our modern world, from lasers to computers, rely on quantum mechanical effects to work, and these things were designed by humans. By any practical standard, there are people that understand our quantum mathematical formalism. Issues of interpretation aside, this is because they spent time deliberately practicing and internalizing this new way of seeing the world.

There are two important lessons to be pulled from this. First, understanding things outside of our own everyday experiences is challenging but not impossible. Second, the information has to be made available for anyone to learn anything. Both lessons necessitate deliberation and careful thought, which can be hard and scary in their own right. It is almost always easier to not put the effort in, to just accept that which you have experienced for yourself as the whole of reality.

At that point, the holes in our understanding are not so much filled in as covered up. Anything trying to fill the hole underneath must perturb the covering, and in that way becomes a threat to an already tenuous sense of security. This applies to quantum mechanics and many other important physical theories, but also to the state of our politically divided nation. People live fundamentally different lives that lead them to believe in and vote for fundamentally different things. Nobody can understand each other when they do not make the deliberate effort to, which halts discourse and, ultimately, our society's forward progression.

PHOTO BY PIXABAY

SCALING DOWN: MICROFLUIDICS GIVE RESEARCH A BOOST

PHOTO BY SHUTTERSTOCK

BY DAVID ROSENBERG, CHEMICAL ENGINEERING, 2020

DESIGN BY ANNIE LEE, DESIGN, 2019

Consider one of your cells. Over one billion proteins produced from around 20,000 genes perform hundreds of millions of chemical reactions, all in a space smaller than a tenth of a microliter. Yet to analyze just one of these genes in a typical laboratory requires trafficking 20 microliters of fluid through several expensive benchtop machines, adding various chemicals by hand at each step. The process can take several hours. To extract meaningful data on the complex interactions within or between live cells, such methods can be ludicrously expensive and difficult. The rising field of microfluidics addresses this by allowing chemistry and biology to operate at a scale closer to that of the systems they examine.

Microfluidics are a broad class of chips that manipulate tiny volumes of fluid to miniaturize laboratory analysis. They are partly derived from the integrated circuits used in electronics, and provide a comparable function for chemistry. The chips, which are a few centimeters on a side and move liquids or gasses through channels up to one millimeter wide, can rapidly perform a series of reactions and analytical processes, sometimes performing hundreds in parallel. This is accomplished by using syringe pumps or an electric field to move different fluids through channels controlled by miniature valves. The channels can be coated with reagents that bind to specific molecules; for instance, a polar coating can slow the movement of polar molecules through a channel to separate the components of a mixture in a process known as micro chromatography, or antibodies added to the channel can stick to specific targets. In addition, the concentration of different chemicals at any point in a microfluidic chip can be precisely controlled through the channel geometry. Heating elements and electrodes can be printed onto a chip to control local temperatures and produce electric currents. Microfluidic chips are typically transparent, which allows researchers to use fluorescent molecules to label reagents or reactions and to run light or radiation-dependent analysis of products directly on the chips.

The high control over local conditions in a microfluidic allows chips to simulate natural conditions. "Organ on a chip" systems attempt to replicate the cell composition and chemical and physical environment of specific human tissues. For instance, channels with protrusions shaped like the structures of the lungs are lined with the appropriate cells and subjected to pressure fluctuations similar to human breathing while exposed to cigarette smoke to evaluate the impact of smoking on the lung. Such devices allow researchers to observe the real-time impact of drugs and other chemicals on specific parts of the body instead of relying on animal models which must be raised and then autopsied to provide a static snapshot. They also allow researchers much greater control over the conditions being tested and allow analysis of human cells instead of those of other mammals. Organs on chips can also be used to explore the behavior and interaction of microorganisms within the body.

Slava Epstein and his team at Northeastern are using simple microfluidics to examine these and other microbes which can't be cultivated in the restricted environment of a laboratory. Instead of attempting to simulate the conditions in which finicky microbes grow, the Epstein lab developed the isolation chip (iChip) which can collect and grow soil bacteria in their native environment. Microscale wells filled with agar are sandwiched between porous membranes that allow air, water, and nutrients to pass through. Some wells have microbes added beforehand, while others have plain agar and a bottom membrane with large enough pores for species to enter from the environment. The whole chip is buried in soil to collect and grow the cells. The chip's scale allows many samples to be easily taken from a small area and allows molecules to rapidly diffuse through the wells. Last year, the iChip isolated a microbe that produces a novel antibiotic, teixobactin, which evades resistance.

Despite widespread utility, microfluidics remain a much smaller part of research than they could be. This is primarily because of the high degree of customization required to use chips for most experiments. Each chip is tailored to a specific set of functions, and the tools required to design and fabricate a chip are unavailable to most labs. This may change soon as CAD tools for microfluidics become more user friendly and custom manufacturing techniques, which have gotten a boost recently with the popularity of 3D printing, continue to progress. Until then, most scientists will stick with pipettes.

Annual Review of Chemical and Biomolecular Engineering (2011). DOI: 10.1146/annurev-chembioeng-061010-114215

Vitamin Supplements:

Micro Effect on Health for a Macro Hit to your Wallet

BY HUGH SHIRLEY, BIOCHEMISTRY, 2020

DESIGN BY HEATHER OFFERMANN, BEHAVIORAL NEUROSCIENCE, 2018

The days are getting shorter and the nights are growing longer. You might have a sniffle, a cough and a tickle in the back of your throat since the weather has grown cold. Yes, winter is almost upon us, and like many Americans, you may be reaching for your vitamin C tablets to stave off a cold or vitamin D to make up for the lack of sunlight. But maybe you should think twice before reaching for those pills the next time you pass through the vitamin aisle at the grocery store.

More than half of Americans take some sort of vitamin or mineral supplement, fueling a 14.3 billion-dollar industry according to the NIH. However, the law does not require dietary supplements to be approved by the FDA before reaching consumers. This has resulted in dietary supplements that contain upwards of 500 percent of the recommended daily value of any given vitamin and mineral in a single pill. But vitamins and minerals can only be good for you, right? Well, no. Minerals like iron, iodine, and zinc can all be harmful when taken in large doses. Vitamins are more complicated than their labels suggest.

Vitamins come in two categories: water-soluble and fat-soluble. Water-soluble vitamins like vitamin C and the B vitamins are easily assimilated by the body and can travel freely through the bloodstream. They require significantly less energy for the body to absorb and transport than the fat-soluble vitamins like A, D, E, and K, which require proteins to move through the blood. According to the CDC and the WHO, fat-soluble vitamins can pose risks if taken in large doses. Excess fat-soluble vitamins in the blood are stored in body fat. According to a meta-analysis in the *Annals of Internal Medicine*, randomized experimental trials have shown that consumption of these fat-soluble vitamins is not correlated with any health benefit, but has been shown to be detrimental to health in some cases.

That's not to say that vitamin supplements are a bad idea in all cases. For example, experts have long known that folic acid supplements can prevent birth defects like neural-tube defects and congenital heart defects. The general consensus among researchers is that pregnant women should still be taking folic acid and iron supplements to help promote fetal development.

Other groups that could stand to benefit from vitamin supplements include vegetarians and vegans. "Particularly for vegans, they need to be very cognizant that they get all the essential nutrients," said Professor Carmen Sceppa, professor and chair of the Department of Health Sciences at Northeastern University. Vegans and vegetarians could be lacking in nutrients, such as vitamin B12, calcium, and iron, which are typically found in animal products.

Vitamin D and Omega-3 fish oil supplements are among the more popular nutrition supplements taken by Americans, but are they doing anything for the huge numbers of Americans taking them? Vitamin D is often recommended to women past the age of 35 to protect bone health and is also a key component of how the body absorbs calcium. "The evidence suggests that as bone mass declines with age, you really need that extra amount of nutrients," noted Sceppa.

Omega-3 fish oil is a different story. The original idea was that taking supplements instead of eating fatty fish would provide the same benefits. However, randomized trials with people who have recently had heart attacks do not show a trend towards a benefit in taking Omega-3 supplements. Those who took fish oil pills had the same rate of recurring heart issues as those who did not take them.

So, as the weather turns cold and the nights grow longer, instead of reaching for a bottle of pills with the hopes of staving off a winter cold, maybe look to your diet for a solution instead. The best way to reach micronutrient needs is by consuming them in food.

Annals of Internal Medicine (2013). DOI: 10.7326/0003-4819-159-12-201312170-00011.

Nutrients (2013). DOI: 10.3390/nu5114760.

MEET YOUR MICROBES

BY MATTHEW DEL MASTRO, BIOLOGY, 2017

DESIGN BY HEATHER OFFERMANN, BEHAVIORAL NEUROSCIENCE, 2018

Growing numbers of Americans are paying companies to gather detailed information on the lives of their closest neighbors. This might suggest a court case in the making, until one considers that our nearest neighbors are not the humans around us, but the microbes living on us and inside us. From the moment of birth, the human body becomes a sprawling metropolis inhabited by a complex and dynamic microbial population. Furthermore, the burgeoning communities that range from the surface of our skin to the inner linings of our guts aren't just along for the ride; studies have shown that microbial action impacts what we look like, how we feel, and even how we behave. Specific microbial makeups have been linked to obesity, depression, sleep quality, and an ever-expanding dossier of diseases from eczema to cancer.

However, we are not completely subject to the whims of our microbes. Research has shown that the composition of our microbiota is in part determined by factors we can control: the foods we eat, the amount we exercise, and the environment we live in. This two way relationship raises the tantalizing prospect of a future in which we can analyze our microbiomes, identify friends and foes, and fine tune the population to achieve the health outcomes we desire. This idea is already being touted by manufacturers of probiotic supplements. But is it really so simple? uBiome, a San Francisco based company specializing in microbiome sequencing, has the tools to investigate this question, and they're offering them to anyone with a credit card and some bacteria to spare. The commercialization of microbiome analysis has the potential to advance citizen science while unlocking new opportunities in research and medicine.

uBiome's success at transforming cutting edge molecular biology into a consumer-friendly product is immediately evident; the sampling kit, which starts at $89.00, features sleek packaging that connotes an iPhone more than a set of chemical reagents. Depending on the package ordered, the customer collects bacterial samples from the skin, mouth, gut, genitals, or nose. Once uBiome receives the samples, they use DNA sequencing to identify the specific bacteria within. Then, the results are returned through an online interface, the "Microbiome Explorer." One of the key functions of the Explorer is to highlight a user's levels of specific "probiotic" bacteria that studies have correlated with positive health outcomes. Bifidobacteria and Lactobacilli are familiar names from television advertisements for probiotics. However, many of these supplements lack evidence for their claims, and without FDA regulation there is little to make sure that consumers aren't flushing money down the drain in pursuit of better health. This is theoretically where uBiome could step in to empower consumers. One could purchase two gut analysis kits and take samples before and after a month of probiotics. If the results showed a great increase in the bacterial varieties advertised on the bottle, this would certainly provide some evidence in favor of the supplement.

Despite the excitement drummed up by such citizen science, it is difficult to draw truly meaningful conclusions from any one person's experience. The real power of the uBiome project may instead lie in the aggregation of data collected from everyone who sends in a sample. All customers have the option to complete a survey describing their health and lifestyle; as this data set grows to include tens of thousands of people, large scale trends can be identified.

The company is already beginning to leverage this idea into the healthcare setting with the recently announced SmartGut clinical diagnostic. DNA analysis can identify potentially pathogenic bacteria in patients with serious gastrointestinal symptoms, but many of these organisms are always present in the body to some degree. They are kept in check by the immune system and the growth of other non-harmful or beneficial organisms. How can a doctor tell if the presence of a pathogen is causing symptoms? The data from uBiome's citizen scientists may provide an answer. The company can use the consumer data to establish normal ranges for potential pathogens in healthy subjects. If a sick patient presents a pathogen thriving far above this ceiling, it could well be the cause of illness.

Furthermore, uBiome is not hoarding this data for itself. The company has established partnerships with numerous academic research institutes including Harvard, Stanford, and the University of California at San Francisco. Topics of investigation include the effects of long-term antibiotic use and the connection between personality and microbial makeup. From the grassroots to the Ivy League, commercial microbiome analysis is deepening our knowledge of the microbial world and improving lives.

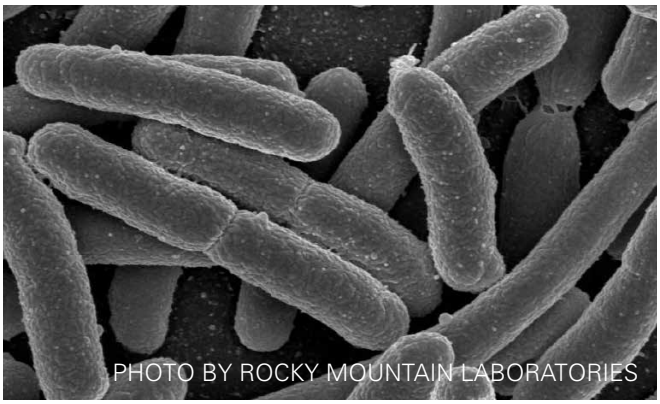
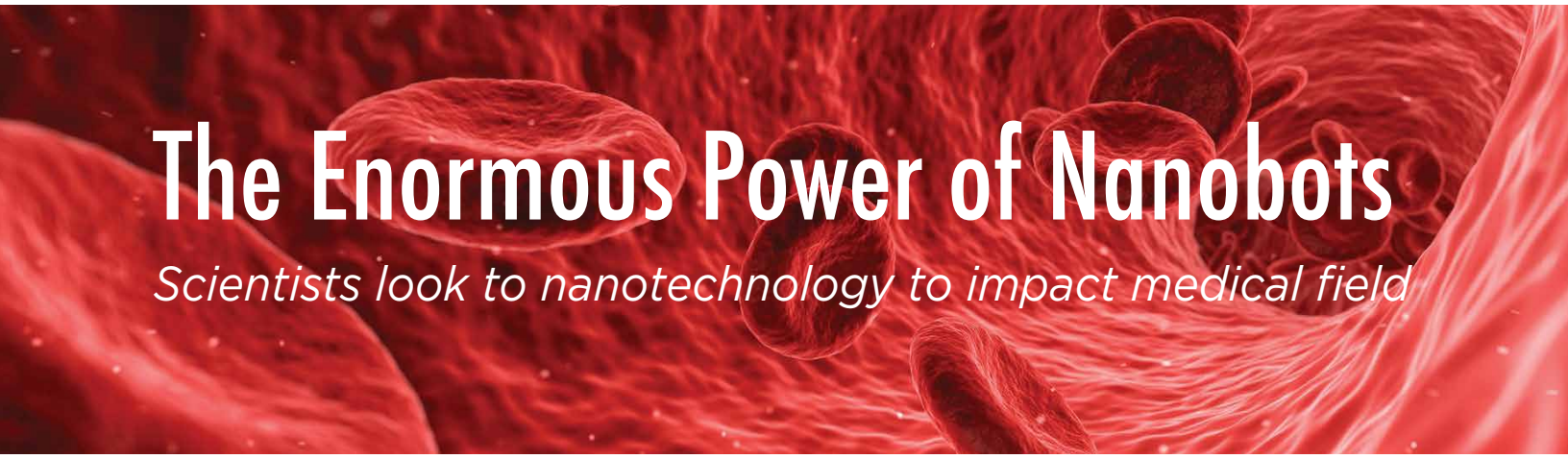


PHOTO BY ROCKY MOUNTAIN LABORATORIES



The Enormous Power of Nanobots

Scientists look to nanotechnology to impact medical field

BY ARIA ELAHI, BIOLOGY, 2017

DESIGN BY ANNIE LEE, DESIGN, 2019

At the moment, the world of nanorobotics is more of a dream than a reality. However, dreams are worth thinking about, as the many scientists that are designing nanorobotic systems for the human body would agree.

In the medical field, there is great potential for nanotechnology to be used in the field of hematology. This provides a myriad of improvements to health care such as emergency transfusions of non-blood oxygen carrying compounds. A respirocyte is the current design of a nanorobot that has yet to reach its application stage. This device collects oxygen as it passes through the respiratory system, collects carbon dioxide from tissue to be released in the lungs, and metabolizes circulating glucose to power itself. This will help individuals that suffer from severe blood loss and provide a much safer and more effective alternative to blood transfusions.

> “These devices might be able to detect life-threatening health conditions and the progression of chronic diseases such as cancer.

However, it does not stop there; the possibilities with nanorobots seem endless. Neurology is another field that can be expanded upon greatly with the addition of nanorobots. These devices can perform tasks such as detection of pathology, intracranial monitoring and pharmaceutical delivery. Nanorobots will allow doctors to keep track of even the most minute details of the patient's neurological system.

Furthermore, there is a strong therapeutic application for nanotechnology in this field. The capability to treat spinal cord injury and nerve damage can advance immensely if nanorobots are able to carry out functions such as improving nerve reconnection and promoting regeneration by adding a variety of growth factors. Furthermore, this technology can carry out surgeries that are extremely difficult to perform using conventional methods. A nanoknife can be used for functions such as axon surgery in order to manipulate axons to improve the nervous system. This is only one of the many ways that nanorobotics can allow for the construction and deconstruction of entire sections of the nervous system.

Researchers also have a specific way for these nanorobots to solve a health issue that many physicians have had great difficulty treating. Cerebral aneurysms are known for their high mortality: 10 percent of patients die before reaching a hospital, 25 percent die within 24 hours of aneurysm rupture, and nearly 50 percent die within 30 days. There is a silver lining in treating this deadly disease and that may be nanorobotics. A design has been proposed by Cacalanti et al. for a nanorobot that has the capability to detect the formation of an aneurysm by detecting an increase in nitric oxide synthase protein which is an early indicator of cerebral aneurysms. If nanorobots are able to communicate to one another, they may be able to coordinate to not only solve medical issues but provide doctors with information before these issues even occur.

Using nanorobots to monitor and screen the human body has created a lively discussion amongst scientists regarding what that might entail. These devices might be able to detect life-threatening health conditions and the progression of chronic diseases such as cancer. They will allow doctors to act much earlier and thus more successfully towards treating what could be critical health problems.

The potential application of nanorobots in the medical field has opened an entire world of possibilities that researchers can pour all their creative energy into. Many envision the future of robotics as one in which robots and humanity remain two separate entities; however, this may not be the case. It just may be possible that nanorobotics and humanity may converge to create something entirely new. Only time will tell.

Amer J Robot Surg American Journal of Robotic Surgery (2014). DOI :10.1166/ajrs.2014.1010

PHOTO BY PIXABAY

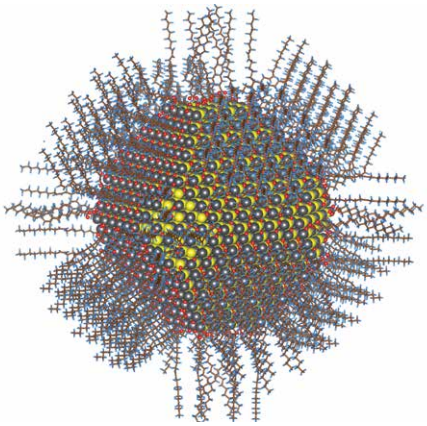
Small Particles Can Make A Big Difference

BY CICELY KREBILL, BIOLOGY, 2019

DESIGN BY ANNIE LEE, DESIGN, 2019

In recent years, the integration of nanotechnology and medicine has become increasingly prevalent. This field, known as nanomedicine, has captured the attention of many including Northeastern University professor Dr. Sridvas Sridhar, - lecturer on radiation oncology at Harvard Medical School, and Director of Northeastern University's CaNCURE program. When asked about the big push in this field of research, Dr. Sridhar says it is simply because "if you look at many of the biological processes in humans, they occur at the nanoscale. So if you want to interact with them, you have to make things that are very small." One way researchers are trying to interact with the human body is through the use of nanoparticles, which are small engineered particles that can absorb and carry other compounds, as well as be taken up in certain biological processes within the body. This makes them particularly attractive for use in drug delivery and imaging.

In terms of targeting a tumor for both drug delivery and diagnostic imaging, the key about these particles is their size. Dr. Sridhar, who works with nanoparticles in the realm of cancer treatment and imaging, says, "If you want to deliver drugs to a tumor, if you make those drugs too big, like larger than microns then they won't get into the pores and into the tumors. If you make them too small they will just get eaten up by other entities and they won't get to the tumors". Dr. Sridhar explains that what is important about these particles is that "you can functionalize them in the right way to target tumors to circulate for long times and all of that occurs at the nanoscale."



NANOPARTICLE

Cancerous tumors are not the only thing nanoparticles can target. They have also been researched for use in fighting bacterial infections, cardiovascular imaging and rapid diagnostics for infectious diseases, among other promising clinical applications. One recent application of nanoparticles is their potential use in controlling blood clotting. The ability to artificially manage blood clotting is limited, which provides serious concern for wound healing and surgery where its management is necessary to ensure patient safety. In these situations, anticoagulants are used to slow or stop bleeding, but these medications are riddled with problems. One of the largest limitations of these drugs is that there is no antidote to reverse their effect. Because of this, reversing their effect is largely based on clearance of the drug from the body, which varies largely between patients.

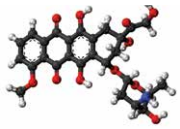
One lab group under Dr. Kim Hamad-Schifferli at both the University of Massachusetts Boston and MIT is using nanoparticles to address this problem. These particles are being used to interact with thrombin inhibitors, as thrombin is a key player in forming the blood clot. Researchers in Dr. Hamad-Schifferli's lab used two different nanoparticles with differing excitation states, meaning the two nanoparticle types will be triggered to release their payloads by different laser irradiation wavelengths. These two nanoparticle types allow clinicians to target the release of one payload, but not the other. From there, they paired one nanoparticle type with the thrombin inhibitor and the other with the complementary DNA strand. When the complementary DNA strand is released, it base pairs with the thrombin inhibitor acting as an antidote to stop the inhibition and allow for coagulation. This effectively works as an on/off switch, with the hopes of allowing clinicians to more effectively control coagulation through selective radiation. The idea behind it is that the clinicians will be able to select which nanoparticles will release their payloads by hitting the nanoparticles with a specific laser at different wavelengths allowing for the ability to start or inhibit coagulation. This is just one of the many innovative ways researchers and clinicians are hoping to use nanoparticles, and illustrates how the possibilities of the impact that nanoparticles can have on the medical field are seemingly endless.

Because of this, there is a new push to get students involved in nanomedicine research earlier on in their education by both researchers in the field, like Dr. Sridhar, and federally funded institutions. One such collaboration, the CaNCURE program, was started in 2014 at Northeastern with a grant funded by the National Cancer Institute with the goal of encouraging the next generation of students to pursue occupations in cancer research or medicine. This initiative is a part of Northeastern's co-op program and is a partnership between Northeastern University and the Dana-Farber Harvard Cancer Center. Every semester, approximately seven students are selected to participate in this co-op opportunity. From there they are matched with mentors in a variety of clinical or wet lab settings to gain exposure to cancer research in the nanomedicine field. Along with the research experience, the students attend seminars where researchers from Northeastern as well as other institutions come to present their applications of nanomedicine. Overall, Dr. Sridhar, the director of the program, emphasizes that the feedback he has received the CaNCURE experience has been very positive. He knew they "had the basic ingredients, but how well it's gone has been very gratifying and we want to continue that. If anything it's turned out better than I expected."

PLoS ONE (2013). DOI: 10.1371/journal.pone.0068511

PHOTO BY PIXABAY

Targeted Drug Discovery



BY BIRUK ABREHA, CHEMISTRY, 2019

DESIGN BY KYRA PERZ, CHEMISTRY, 2020

Imagine burning down an entire forest with the goal of eliminating a few disease-ridden trees. It may not make much sense; however, this is the approach most commonly used to treat cancer.

Using targeted drug delivery to selectively administer drugs to the disease-ridden tissues of the body, as opposed to treatments like chemotherapy and radiation, can increase the overall efficacy and safety of a drug. Targeted drug delivery is a solution that has several benefits over conventional drug delivery, including reducing the occurrence of side effects and lowering the size and frequency of dosages A variety of targeted drug delivery strategies provide researchers and medical professionals a multitude of options to treat diseases.

Researchers at Tzu Chi University in Taiwan and Osmania University in India have developed a clever targeted delivery system relying on nanoparticles. In essence, the nanoparticle-drug conjugate functions as a homing device for the drug. The researchers bound Doxorubicin, an anticancer agent, to gold nanoparticles 10 nanometers in diameter. When this nanoparticle-drug conjugate is administered, it is ingested by tumorous cells with the Doxorubicin remaining bound to the gold nanoparticle. Once it encounters the acidic environment in a tumor cell, the drug is released from the nanoparticle. It interacts with the cell's DNA, preventing further cell replication and stalling tumor growth. This drug delivery system can provide a nearly tenfold difference in targeting tumorous cells over healthy cells.

The method described above simply improves upon the of delivery of the drug to the affected parts of the body. It does not rely on a novel anticancer agent; in fact, Doxorubicin is widely used in the treatment of various cancers including leukemia, breast cancer, and Hodgkin's lymphoma. By combining this pre-existing drug with an improved delivery system, the drug is made safer and more efficacious. Furthermore, targeted drug delivery is not limited to the treatment of cancers; delivery systems have been developed to target respiratory and brain-related illnesses as well.

PHOTO BY JYNTO

And the Nobel Prize Goes to...

BY ADRIANNA GRAZIANO, BIOLOGY, 2019

In 1901, Swedish inventor Alfred Nobel established the prestigious Nobel Prizes to celebrate notable academic, cultural, and scientific contributions. During the first week of October, the 2016 Nobel Prizes in Physiology or Medicine, Physics, and Chemistry were awarded to and split among a total of seven intellectual, determined, and successful scientists for supporting and pushing their fields into new ways of thinking.

The **Nobel Prize in Physiology or Medicine** was awarded for the discovery of autophagy mechanisms to Yoshinori Ohsumi from the Tokyo Institute of Technology in Japan. Lately, autophagy – the fundamental process by which cellular components are recycled and degraded - has been of increasing interest to scientists because of its involvement in physiological processes such as a cell's stress response to starvation. Ohsumi was responsible for identifying essential autophagy genes in the 1990s and for the current understanding of "self-eating" metabolic pathways in yeast. He also demonstrated the similarity between the mechanism of autophagy in yeast and human cells. His research will impact future understanding of the autophagic processes involved in cancer and neurological diseases.

Three laureates received the **Nobel Prize in Physics** for their theoretical discoveries of topical phase transitions and topological phases of matter: David J. Thouless from the University of Washington in Seattle, F. Duncan M. Haldane from Princeton University, and J. Michael Kosterlitz from Brown University. Topology is the mathematical study used to describe geometric and spatial properties of a figure that only change stepwise, and are therefore unaffected by deformations that change its shape or size. The research of Thouless, Haldane, and Kosterlitz has collectively overturned theories of topological phases and revealed the secrets of exotic matter within superconductors and thin magnetic films. This will influence possible materials that may be used in next-generation electronics and future quantum computers.

The **Nobel Prize in Chemistry** was awarded to Jean-Piere Sauvage from the University of Strasbourg in France, Sir J. Fraser Stoddart from Northwestern University in Illinois, and Bernard L. Feringa from the University of Groningen in the Netherlands. Since 1983, each of these scientists has been individually developing "miniaturized machines" to control molecular systems and their movements in an energy-filled state. Feringa developed the first molecule motor that can rotate a glass cylinder 10,000 times bigger than the motor itself. These machines have the promising potential to be used in industry development to create new materials and storage systems.

PHOTOS BY TOBIAS 1984 & CYCLEDEKREBS

Gluten-Intolerance Disorders: Breaking Them Down

BY MEREDITH CRAIG, PHYSICAL THERAPY, 2021

DESIGN BY KYRA PERZ, CHEMISTRY, 2020

Anyone who has perused a supermarket in the last few years has probably noticed a growing "gluten-free" section in most stores. Many are choosing a gluten-free diet as a lifestyle. Although one study shows that 29% of American adults choose to eliminate gluten from their diet either partially or completely, there is a much smaller percentage of the population that must live without gluten; they have been diagnosed with celiac disease, non-celiac gluten sensitivity, or a wheat allergy.

Despite its increasing popularity, many are still confused about what exactly gluten is. Put simply, gluten is a mixture of proteins found in wheat, barley and rye. It is also found in triticale, a hybrid grain consisting of wheat and rye. Despite popular belief, oats are naturally gluten-free - instead of containing the gluten protein, they contain proteins known as avenins. However, oftentimes, oats and gluten grains are farmed on the same land, leading to a potential cross-contamination of the products. As a result, people on gluten-free diets must be cautious about consuming them, especially if they have celiac disease.

Celiac disease is the population's rarest gluten-intolerance disorder, with less than 1% of population living with this diagnoses. Ultimately, gluten causes severe gastrointestinal pain and side effects, including but not limited to vomiting, bloating and abnormal bowel habits in these patients. When people with celiac consume gluten, they are unable to fully hydrolyze the gluten proteins, which induces an immune response. Toxic peptides are also activated and sent to damage the intestine, making it especially dangerous for people with celiac to consume gluten long-term.

While researchers know a great deal about celiac disease, much less is known about its related counterpart, non-celiac gluten sensitivity, which affects approximately 5-10% of people worldwide. Just as with celiac disease, those who have non-celiac gluten sensitivity (NCGS) often experience the same severe gastrointestinal pain and side effects. It has also been proposed that NCGS can lead to depression, anxiety and/or schizophrenia. As with Celiac, people with NCGS are unable to hydrolyze the gluten proteins, and a partial immune response is invoked. However, unlike celiac disease, toxic peptides do not attack the intestine, making the disease slightly less dangerous than its counterpart.

Wheat allergies are also fairly prevalent among Americans, as wheat is one of the 8 major food allergens. When people with a wheat allergy consume the product, an allergic response is initiated and an allergen will bind to IgE antibodies. This can cause a variety of responses in patients, including swelling, itching, and in severe cases, anaphylaxis. However, unlike celiac disease and non-celiac gluten sensitivity, no gastrointestinal and/or permanent organ damage occurs. Furthermore, in many cases, children will "grow out" of this allergy, with 29% of cases being resolved by age 4 and 65% by age 12.

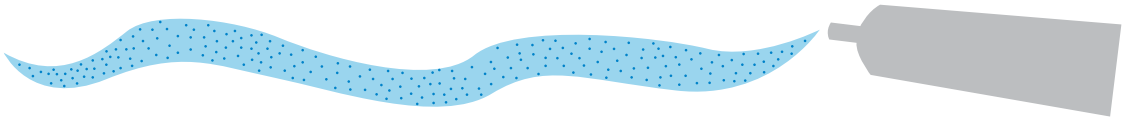
For people who do live with a gluten-intolerance disorder, the only current treatment is to eliminate gluten from their diet. Since this often leads to vitamin, folic acid, zinc and iron deficiencies, it is important that people on such a diet replace gluten with other safe grains, such as quinoa or rice, when possible. They must also be extremely cautious when travelling or eating out, as people are still coming to understand the dangers of the disease and may not avoid contamination of their food with gluten products. Although this may not be a perfect solution, eliminating gluten from their diets greatly improves the quality of life for people who have a gluten intolerance, and will have to suffice until research and technology catches up with the growing popularity of these disorders.

PHOTOS BY: PIXABY, WIKI COMMONS AND FLICKR

Understanding Microbeads as Aquatic Pollutants

BY LUCAS PRINCIPE, ENVIRONMENTAL SCIENCE, 2020

DESIGN BY ANNA LI, BEHAVIORAL NEUROSCIENCE, 2019



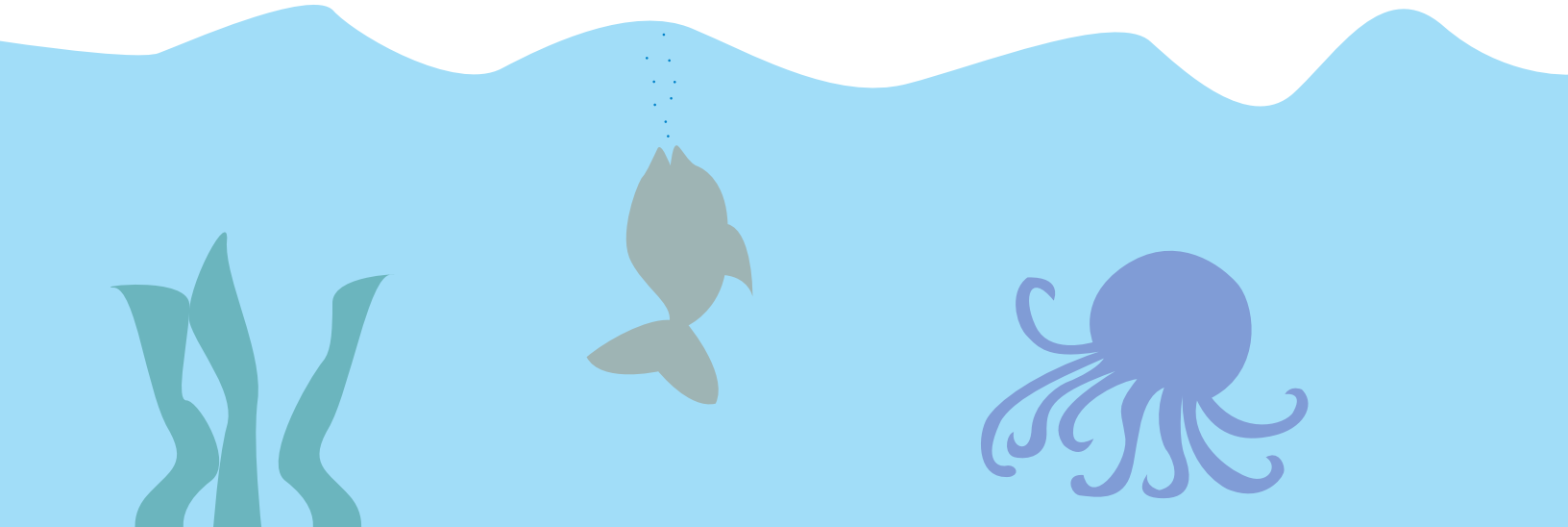
Last December, the United States Congress overwhelmingly passed an initiative known as the Microbead-Free Waters Act of 2015. The law outlines a strategy to prohibit "the sale or distribution of rinse off cosmetics containing plastic microbeads." If you're like most Americans, you've never even heard of a microbead, yet you most likely use them every day.

Plastic microbeads are defined as plastic fragments ranging in size from roughly 50 to 500 micrometers, the latter measurement being about the size of the period at the end of this sentence. They are typically made from synthetic polymers such as polyethylene, polypropylene and polyethylene terephthalate. These tiny plastic particles are harbored inside most everyday cleaning products such as shampoo, body wash, and toothpaste and face wash. They are used as abrasives and exfoliates in hundreds of personal care products. Put more simply, they're the tiny particles in your body wash that scrape off dirt and dead skin. They may seem innocent, but these beads cause a host of environmental problems.

Plastic microbeads were first recognized as a source of pollution in 1991, but they were considered an issue of low priority at the time. Since then, we've found out much more about their hazardous nature. Because microbeads are stored in personal care products, they typically are washed down the drain and ultimately end up in our waterways and oceans. Here is where they cause the majority of their damage. Upon entering waterways, plastic microbeads are known to enter the stomachs of various fish and seabirds, contributing to the ever-growing plastic pollution crisis in our oceans. Currently, it is estimated that over 300 species eat and get caught in plastic litter. What's more, these microplastics are known to essentially soak up harmful toxins that are then transferred to the fish when ingested. For these reasons, microbeads are a large environmental problem for many species.

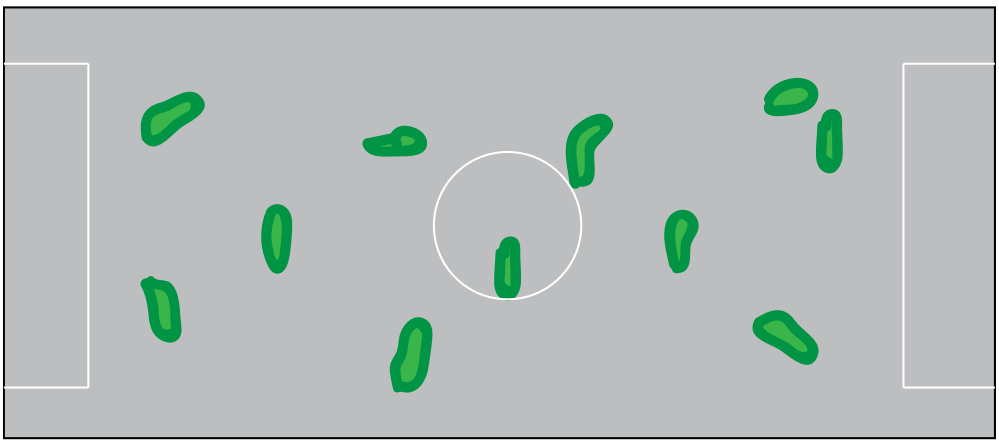
The reason microbeads aren't filtered out in our municipal water treatment facilities is that they are engineered not to do so. They are intended to be washed down the drain with the personal care product, and most are not biodegradable. Due to their small size, it is not possible or realistic for wastewater treatment plants to screen and catch microbeads, which end up being released into the environment via wastewater from the treatment facility. Each personal care product can contain hundreds of thousands of microbeads. A number of conservative estimates identify the number of microbeads emitted per day in the United States to be between three and 23 billion. Clearly, these tiny beads pose a large problem for our domestic waterways.

There is good news for environmentalists, however. As mentioned previously, the United States Congress overwhelmingly passed the Microbead-Free Waters Act last December. Additionally, various countries including Canada, the United Kingdom and the Netherlands are all working towards the elimination of microbeads within the next 5 years. The ban on the bead is just one example of a quick and painless environmental fix; a "no-brainer" so to speak. Companies who manufacture personal care products can easily switch to natural or biodegradable exfoliating and abrasive materials such as pumice or walnut husks. This solution does not drive away consumers and ultimately helps to limit human impact on our oceans and waterways. Regardless of where your party affiliation lies, both sides of the U.S. Congress have ensured that America has been one of the leading countries on this issue which many see as a stepping stone to ending the marine plastic crisis.



LudusScope Introduces Microbiology at a Young Age

ARTICLE AND DESIGN BY HEATHER OFFERMANN, BEHAVIORAL NEUROSCIENCE, 2019



Unlike many career fields that provide clever boxed experiments and gadgets to young aspiring scientists, microbiology is an advanced subject that may be challenging to introduce to kids, as it involves special techniques and machinery for visualization. To Stanford engineer Ingmar Riedel-Kruse, this issue was seen as an opportunity to help kids dive into the realm of microbiology, with the help of an invention based off of a common piece of technology that every kid is now familiar with. LudusScope, a 3D-printed microscope attachment for smartphones, was designed with kids in mind. Because this microscope was made for educational settings, it can be easily printed and assembled by kids with little help from teachers.

According to Kruse and his colleagues, who published an October 2016 study in the journal *PLOS ONE* detailing the benefits of the new tool, the name LudusScope is derived from the latin term "ludus," which has several meanings, including "to play" or "to train," as well the name of a traditional elementary school in ancient Rome. Considering of these definitions, the designers of LudusScope wanted to incorporate an interactive biology game with the educational settings of young scientists.

LudusScope provides a new way to learn about and interact with common microbes, such as *Euglena gracilis*, a single-celled eukaryote that has a light-sensitive organelle which guides the cell towards the source of light. LudusScope consists of a platform to hold a microscope slide containing *Euglena* and a smartphone holder with an eyepiece for the viewer. Each corner of the slide has an LED light source, which serves as the basis for player-controlled movement of the *Euglena* using a joystick. LudusScope has games similar to soccer and PacMan, where the user can control the movement of the microbes using light stimulation, guiding an individual *Euglena* to a particular goal or projected path. All gaming purposes aside, this microscope allows viewers to learn about one of the most fundamental concepts of studying microbiology, which is the ability for organisms to respond to an external stimulus. The light response of *Euglena* is almost instantaneous, allowing players to "influence the cells' orientation and swimming direction via light stimuli in real time," as the study says. The interface of the game also provides users with the real-time velocity of the chosen *Euglena*, a scale bar for correct measurements, and a zoomed-in view of the organism. These features allow for hypothesis testing and modeling, based on simple comparisons users can make between the velocities and behaviors of two different *Euglena*.

The LudusScope was tested on both teachers and high school students with appealing and beneficiary results for both groups. Teachers agreed that the bio-interactive game improved teaching and emphasized the need for more hands-on activities in the classroom, and the students found the system improved their learning of difficult concepts in microbiology. As for now, this smartphone microscope is still being tested, but hopes to significantly cut starter kit costs are aimed to bring the self-builder price from ~$100, to ~$30 with successful mass production. Innovations like LudusScope bring the promise of introducing scientific concepts to kids at a younger age. Hopefully, LudusScope will be seen on the shelves of stores, or distributed to classrooms, sometime in the near future.

Plos Journals (2016). DOI: 10.1371.

Researchers Create Insect-Inspired Self-Healing Material

BY AMANDA BRETTI, CHEMICAL ENGINEERING, 2019

DESIGN BY KYRA PERZ, CHEMISTRY, 2020

Researchers often draw inspiration from nature. One such inspiration comes from insects and how they are able to heal after skin damage. Rather than having a closed circulatory system such as that of humans, in which the blood is contained in vessels, insects have an open circulatory system in which their cavities are filled with a blood-like fluid called hemolymph. When an insect's skin is damaged, the hemolymph is exposed to the air and the phenolic compounds in it become oxidized. Oxidation, which is the addition of oxygen atoms or the loss of hydrogen atoms, changes the chemical structure of the hemolymph. The result is that the hemolymph on the surface quickly solidifies, closing the wound.

> "This may be the first time a self-healing material has been developed that can regenerate and seal itself multiple times without needing external stimuli.

This is similar to the process in which fruit browns shortly after its skin is peeled off. Like insect hemolymph, the inside of many fruits contains phenolic compounds. When the inside of the fruit is exposed to the air, the exposed flesh becomes oxidized, which turns it brown. The lower layers of the fruit's flesh, which are not exposed to the oxygen in the air, remain unoxidized and do not turn brown.

Inspired by this, several researchers in Korea recently developed a self-healing material. They used a phenolic compound called pyrogallol (PG) as well as polyethylenimine (PEI) as a scaffold to support the material. When they combined the two substances and exposed them to air, a film spontaneously formed that separated the liquid and the air. The researchers named this film Re-Seal-gallol. When they removed the film, a new one formed in a couple of minutes. The film could reseal its holes and stick to the surrounding walls.

The researchers believe the film formed when the oxygen in the air oxidized the pyrogallol in the film solution. The new compounds that formed reacted with each other and then with the PEI scaffold, producing microfibers that held the material together.

The researchers tested their Re-Seal-gallol by making it in a lizard-shaped mold and then cutting the film's tail off. A new film reformed over the tail, and it was able to regenerate multiple times with little difference in strength. Notably, this may be the first time a self-healing material has been developed that can regenerate and seal itself multiple times without needing external stimuli.

Besides forming a film, the Re-Seal-gallol solution could also be combined with heated agarose, a large molecule extracted from seaweed, and cooled to form a hydrogel. When a layer of the gel was peeled off using a razor, it regenerated.

The researchers also tested whether they could stretch the Re-Seal-gallol film without changing its strength. They dipped a cotton ball in the Re-Seal-gallol solution, which caused the film to form around the cotton ball. Then they stretched the cotton ball 2 cm and saw that the film resealed any cracks that developed during the stretching.

Overall, the development of this Re-Seal-gallol film is an important step in making self-healing materials. This film may be the first of its kind to be able to regenerate multiple times without the utilization of external stimuli. Such self-healing materials could have many uses, such as in material added to surgical wounds, sturdier packaging material, and scratch-resistant vehicle coatings. Although more research must be done on these films, they promise to be an exciting and useful technology.

PHOTO BY MASAKI IDEKA

Mastering MICROgravity

If we want to travel into the final frontier that is space, explore strange new celestial bodies, discover new life, and boldly go where no human has gone before, it is imperative for us to get a better grasp on microgravity and how to live and work in it.

BY SAMANTHA GLASSNER, MECHANICAL ENGINEERING, 2019

DESIGN BY ANNIE LEE, DESIGN, 2019

What is Microgravity?

Microgravity is a state in which the effect of gravity on an object is minuscule enough that it seems as if the object is weightless. On Earth's surface everything is tethered down by gravity but as you move further and further from the center of the Earth and out of its atmosphere, gravity's effect decreases. Better understanding of how objects and systems act when broken free of gravity's pull requires physical testing in microgravity. Today we aren't able to simulate gravity on the ground so scientists have developed other methods to do so in the skies and beyond.

Simulating Microgravity - The Vomit Comet

The Vomit Comet is an infamous airplane which was used by the National Aeronautics and Space Administration (NASA) to conduct tests in microgravity without having to transport people to the ISS. This KC-135 Boeing aircraft was adopted by the NASA Reduced Gravity Program to test hardware and humans in space conditions. To simulate weightlessness, a vehicle must fly in giant parabolic arcs, which produce around 20 to 25 seconds of approximate microgravity. Typically, this aircraft would conduct 30 to 40 of these jarring parabolas in a multiple hour mission, in which NASA would train astronauts and conduct experiments on how things operated in a microgravity environment. NASA ran a Reduced Gravity Student Flight Opportunities Program, which challenged university students to design zero gravity experiments. The winning teams won a chance to run their tests on the Vomit Comet. Furthermore, this plane was even used to film some of the weightless scenes in Apollo 13.
Today you could experience the wildness of microgravity for yourself, at a price. Companies like ZERO-G are using similar aircrafts and are bringing passengers on the ride of their lives. As space travel is becoming more privatized, more companies are getting in on this opportunity to capitalize on experiences that are out of this world, like simulating microgravity.

Wonders and Woes of Weightlessness - Research in the International Space Station (ISS)

The ISS is a lab in space orbiting around Earth, where astronauts live and work in zero gravity, providing an unparalleled ability to test in unique microgravity conditions. Thus, astronauts have very regimented schedules in which they must conduct experiments that many different scientists have constructed on Earth with the intention of testing their subjects in weightlessness. Although microgravity allows for amazing experimentation, it is not without its drawbacks. Along with the countless specimens that astronauts bring up to the ISS to study, they themselves are creatures of investigation to study microgravity's effect on the human body. One ongoing study involves investigating how spaceflight affects ocular health. Many astronauts have documented changes in vision, due to fluid shifts in the body from extended weightlessness. Studies like this are crucial to expand our knowledge on the biological ramifications of long-duration spaceflight.

With weightlessness comes a whole new set of rules for concepts we have long held for granted on Earth—one such variant is liquids in space. There are a lot of crucial systems involved in space travel involving liquid, such as the water supplies, coolant systems, urine recycling devices, and fuel. The tricky part is that fluids act in a very un-intuitive way in space; we can see just how different fluids react in space by looking at one study done on the ISS involving a fluid near and dear to many of us—coffee. With no gravity, a stereotypical daily routine like drinking coffee becomes an engineering feat to be tackled. To allow astronauts to enjoy their morning cup of joe without drinking it out of a pouch with a straw as they usually do, scientists created a zero gravity coffee cup. This cup takes advantage of the capillary effect, which causes fluids to naturally flow along any narrow-angled channel where two surfaces meet. Countless routines such as this must be completely re-imagined and tailored for space and its wondrous weightlessness.
As we try and voyage further to explore beyond our planet, investigations like these that focus on uncovering the effect of microgravity on our bodies and how to adapt our way of life to space will become even more vital.

PHOTO BY KODAK EASYSHARE Z915

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