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wisconsin engineer

SUMMER 2017 VOLUME 121, NUMBER 3

9th Annual Photo Contest

2017 Photo Contest Winner:

Dumbo by Akshat Khanna

Featured Articles: Genetic Evolution p. 3 • Solar Eclipse p. 14 • Artificial Eye p. 16

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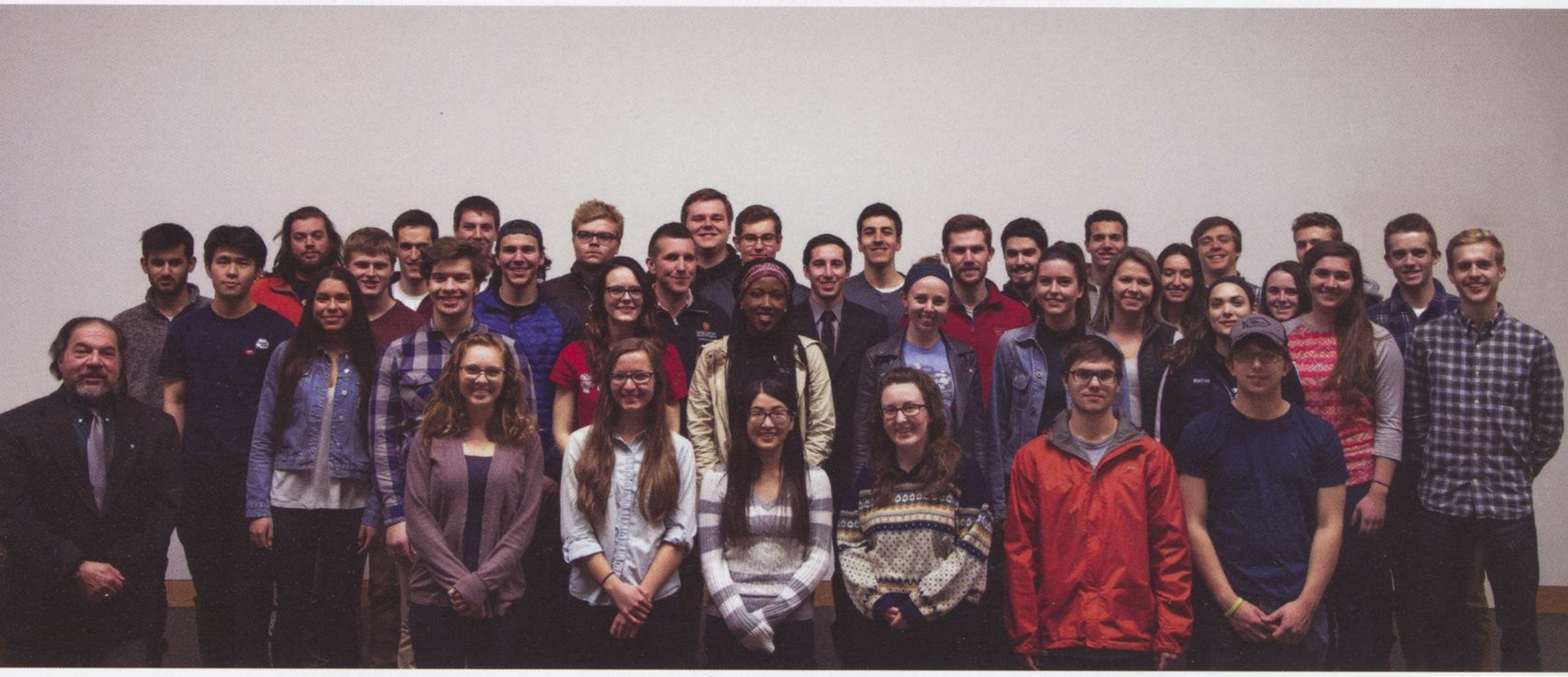

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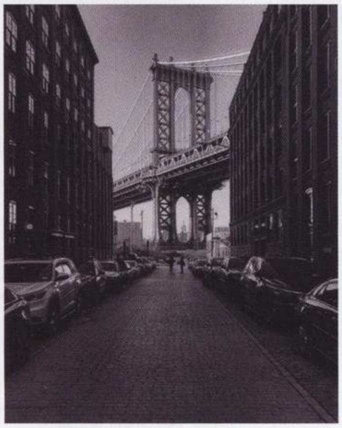
General



Cover photo:
9th Annual Photo Contest Winner,
Akshat Khanna - "Dumbo"

A Note From the Editors

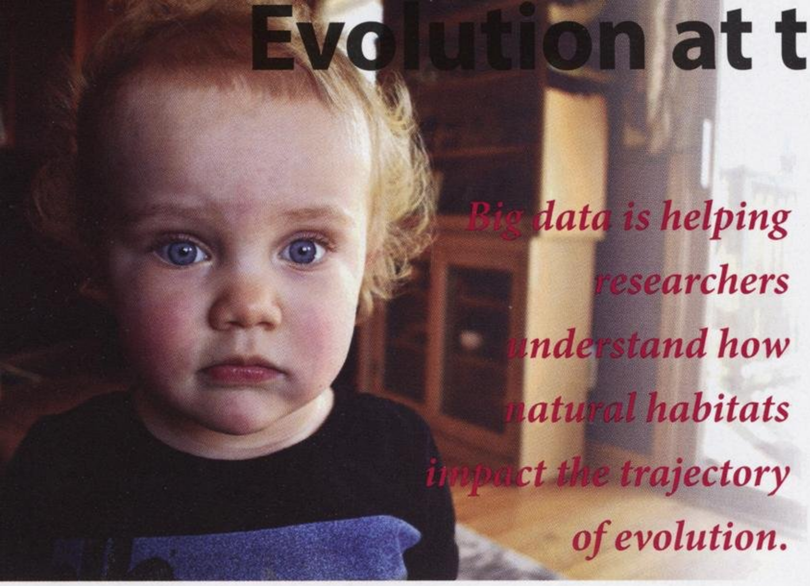
While the Wisconsin Engineer Magazine is pleased to publish this Summer 2017 Issue, we do so with heavy hearts. It is with sadness that we report the passing of one of the magazine's past members, Kate Slattery.

Kate passed away unexpectedly last June in San Francisco, where she worked at SolarCity. Kate graduated from the University of Wisconsin-Madison with a degree in Mechanical Engineering. As a student, Kate wrote for the Wisconsin Engineer in stories such as "3D Printing: The Gateway into the Future of Design" (May 2013) and "The Secret Behind Pharaoh's Chariot" (October 2013). Additionally, Kate mentored female engineers and wrote a children's book, "Fly with Maya," to teach girls about what she saw in engineering and that they could follow their dreams. She loved traveling and spent a lot of time outdoors. An enthusiastic, energetic individual, Kate truly lived life to the fullest.

We would like to dedicate this issue of the Wisconsin Engineer to Kate Slattery. Our thoughts are with Kate's family and friends, some of whom are still at UW-Madison. Kate was a daughter, sister, and friend of many – she will be remembered and missed as the wonderful individual that she was.

- The Wisconsin Engineer Editorial Staff

Evolution at the Molecular Level



Big data is helping researchers understand how natural habitats impact the trajectory of evolution.

Evolution might be the answer to the oldest question of all: Where do we come from? However, to understand evolution, scientists must study processes that take place over thousands, millions, and even billions of years. Since the era of Darwin, the field of genetics has been the window through time that makes this possible. In modern evolutionary research, DNA sequencing techniques and advancements in computer science have finally brought the answer to our question within reach.

Considering the far-reaching implications of understanding the progression of life on Earth, Professor John Pool, of the Genetics and Biotechnology Center at UW-Madison, is searching for answers in an unlikely place. Pool describes his work as studying "the hidden mechanisms behind evolution by analyzing the genomes of Drosophila melanogaster" – also known as the common household fruit fly. Fruit flies are widely used in genetic research as model organisms because they are easy to work with and have roughly the same number of genes as humans, despite our outward differences.

This startling common ground between insects and ourselves has become clear over decades of research. At the beginning, genetic studies were slow and inefficient. Recalling his graduate studies only 10 years ago, Pool notes that he "was only able to study one little piece of the genome at a time." This was accomplished using a technique call Sanger Sequencing to figure out the exact order of DNA building blocks (A, T, C, or G). The Sanger method first targets a piece of a DNA molecule by directly binding a primer in front of the region of interest. Then an enzyme is used to make many small copies of the target region that extend in varying lengths from the target. From here, the DNA sequence can be determined by sorting each copy by size and identifying the last building block in each copy. Although the Sanger method was considered to be the gold standard of DNA sequencing for a long time, it was eventually replaced by next generation sequencing methods which sped up the process by orders of magnitude.

Pool witnessed the introduction of next generation sequencing and comments that "it brought on a revolution in the biological sciences." Compiling the complete genome of an entire species can be compared to assembling a puzzle with billions of pieces – except thousands of pieces are missing, millions more have duplicates, and all of it is too small to see with the naked eye. Modern DNA sequencing was the great leap forward in genetics that made it possible to fit all of the pieces together. By decoding entire genomes at a time instead of the small segments yielded by the Sanger method, Pool explains that he now has "a complete data set for studying genetic variation between and even within populations."

The Pool lab has used modern DNA sequencing to analyze the complete genome of hundreds of flies from populations all around the world. This provides mountains of data, as each fly has a different combination of tens of thousands of genes made up of millions of DNA building blocks. Because it is too much information for a human to ever sort through, Pool uses advanced computing methods to find genetic similarities and differences between flies that live in different parts of the world. Then, by comparing the differences in the genetic code of flies with different native environments, Pool can make assertions on how evolution has shaped the genome of the species as a whole.

All of the fly populations studied by the Pool lab were captured in the wild, some of which were caught by Pool himself in African countries. This differs from typical fruit fly studies which artificially modify the genome and look for the impact this has on the organism. Because Pool is looking at natural genetic variation, he can quantify some of the subtle forces that impact the trajectory of evolution. This involves determining how natural selection helps a population adapt to a new habitat on a molecular level and considers the effect that population-level events, such as a sudden change in environment that drastically reduces population, have on the species genome.

For example, Pool is currently running a study on two populations of flies from Ethiopia. One population is native to the lowland areas and the other comes from a high-altitude mountainous region. Although these populations could exist within miles of each other, they are living in dramatically different habitats. The high-altitude population is accustomed to colder temperatures, lower oxygen level, and more UV radiation. By comparing the genomes of the two populations, Pool can determine how the high-altitude population adapted to handle these changes on a molecular level. Because the high-altitude population is likely descended from the lowland flies, Pool can then determine how the first population of lowland flies to exist in the high-altitude region was able to evolve into the population that exists today.

At first, it may seem difficult to justify using such expensive techniques and globally coordinated research to study such a small and unimportant organism. By Pool's own admission, understanding fruit fly population genetics has no direct "economic, medicinal, agricultural, or industrial value." This classifies Pool's work as basic science, research that has no direct application but can provide discoveries for use in applied fields. Currently, researchers in basic science have a more difficult time getting funding compared to pressing issues like climate change or incurable disease. But before anyone pulls grants for fruit fly studies, Pool stresses that "the applications of understanding how populations pass genetic information from one generation to the next could potentially be limitless."

A complete knowledge of how genes are passed between populations, and even gradually yield a new species, could solve some the biggest problems in the world today. Crops could be genetically designed over time to end world hunger without the use of "unnatural" genetic engineering. Plants with medicinal value could be naturally bred to increase their yield and decrease pharmaceutical costs. Invasive species could be stopped in their tracks by fortifying native wildlife with a population more resistant to the new threat. It will take a long time to accomplish all of these feats of science, but the first step is basic research to understand the evolution of common household fruit flies.

Written by: Tom Eithun

Photography by: Lili Haskins

Design by: Patricia Stan

Cherish or Perish

Energy is the health of our home, the opportunity for technological and economic advancement, the answer to world peace, the key to prosperity, and the security of our future on this planet.

Today, as the population soars into the billions and demand for natural resources like crude oil and natural gas is still on the rise, energy has become a hot commodity. Entire industries have been established that are devoted to creating sustainable and renewable sources of energy. Wars have been started over energy availability. Countries have been created and destroyed in the struggle to achieve energy security. It seems that energy is the new currency; whoever controls the energy supply has the power to control the world. Because energy has become such an indispensable commodity in this over-populated, technology dependent world, it has become a critical global problem to increase the availability, sustainability, and overall security of energy for the near and long-term future.

> **"If there was one thing that unites all of these research thrusts, it is that people care about what is going to happen in the next generation." – Coxhead**

Why is this so important? Wisconsin Energy Institute Associate Director Mary Blanchard explains, "Energy research is so important because we all use energy every day. It's part of our standard of living, and it's part of how we even have economic activity. If we're able to improve the way we are sourcing and using energy, that offers a real advantage to our society; it can save money for consumers, it can offer competitive advantage for industry." Our reliance on energy has, however, led to a rise in world temperatures that is tainting all aspects of our lives: the environment, human health, even local and global economies. To counteract these negative effects, we will need to identify strategies for clean, efficient, and cost-effective energy while continuing to pursue the advancement of economic growth.

This is part of the vision of the Wisconsin Energy Institute (WEI) at University of Wisconsin–Madison. At WEI, they seek to increase energy-related research, to educate the public and future leaders in energy, and to support applied research initiatives to move technologies toward commercialization. For Blanchard and Interim Director Ian Coxhead, this vision defines their careers.

The WEI supports the energy-related research of over 140 faculty and scientists on campus at the University of Wisconsin–Madison. These researchers are agronomists, biologists, chemists, computer scientists, ecologists, engineers, and mathematicians, and their research focuses not only on advancing technology, but on policy and economics, too. Diversity is a central theme to WEI. They are working to create a dynamic environment that focuses on energy's connections to society as well as the broader issue of sustainability. Coxhead, also a professor and Chair of the Department of Agricultural & Applied Economics, says that it's their goal "to make sure that the energy institute continues to develop its personality as the place on campus where people come to talk about energy issues." Energy is in discussions across campus, not just at WEI, and the aim of the institute is to integrate its research and its outreach into the broader campus area.

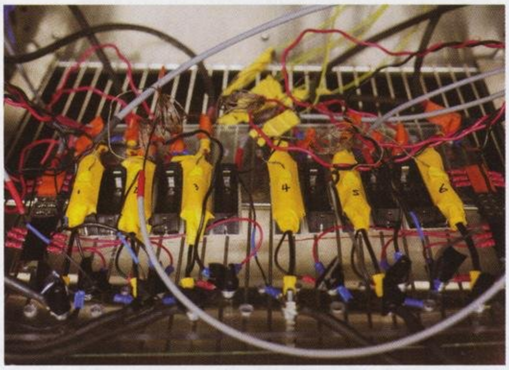
With research expertise in fuels and transportation as well as electricity systems such as wind, solar, biogas, and nuclear, the WEI has a broad reach into the energy research field. The WEI has helped bring the University of Wisconsin–Madison to the forefront in energy research. According to Blanchard, energy currently accounts for about 11% of UW Madison's research portfolio. Within this 11% is a total of $62.7 million of Department of Energy (DOE) funded research at UW-Madison, $28 million of which is (DOE) funded research specifically supported by WEI. The DOE funded projects at WEI include converting biomass into previously petroleum-derived chemicals, improving nuclear fuel testing and safety, modelling the evolution of the US power grid, and designing concentrating solar power plants that make solar more efficient and cost-competitive.

A big question here is whether this funding or the scope of the research in the WEI and similar institutions across the country will change with the new leadership of the DOE. "We don't know yet," Coxhead replies. Blanchard continues, "Secretary Perry has pledged to support all types of energy and to be a strong advocate for the Department of Energy, but it's still very unknown." As of now, it remains unclear whether the funding and positions of the DOE will be consistent with previous years, or if changes are coming.

Closer to home, the University of Wisconsin–Madison will continue its research into big picture energy issues. At WEI and across campus the high-level issues remain unchanged, and individual research groups are focusing on specific components of the big picture problems. These issues in energy are being evaluated from many different points of view including economic growth, economic efficiency, and safety from an environmental standpoint.

Coxhead explains that energy issues are three-sided. There is the supply side, which deals with availability of cleaner sources of energy and potential for new technologies at lower costs and higher competitiveness. Then there is demand, which is how people use energy and respond to incentives. This relates to conservation and understanding how people respond to changes in order to nudge their behavior. There is also a social science dimension that factors into energy issues. This deals with energy security concerns like transmission monopolization in other countries that lead to high levels of inefficiency.

Energy issues of today are multifaceted and research into these issues is even more so. "If there was one thing that unites all of these research thrusts," Coxhead says, "it is that people care about what is going to happen in the next generation." In the upcoming generation, he continues, "there are going to be major global catastrophes certainly with much higher probability." Unity in more efficient supply, conservation, and more efficient and better allocation of transmission must be achieved if we are to keep global warming in check for the future.



Battery energy research granted by Johnson Controls in May, 2016.

Energy enables. From daily life to economic development, from security concerns to protection of the environment, energy lies at the heart of everyone's central interests. Energy can't be undertaken just by the experts any more than hospital consultants can take credit for a healthy population. Rather than defining it as a technical question to be solved by experts, we need to see energy as an issue for everyone because it is an issue for everyone. Energy is the health of our home, the opportunity for technological and economic advancement, the answer to world peace, the key to prosperity, and the security of our future on this planet.

Written by: Morgan Adkins

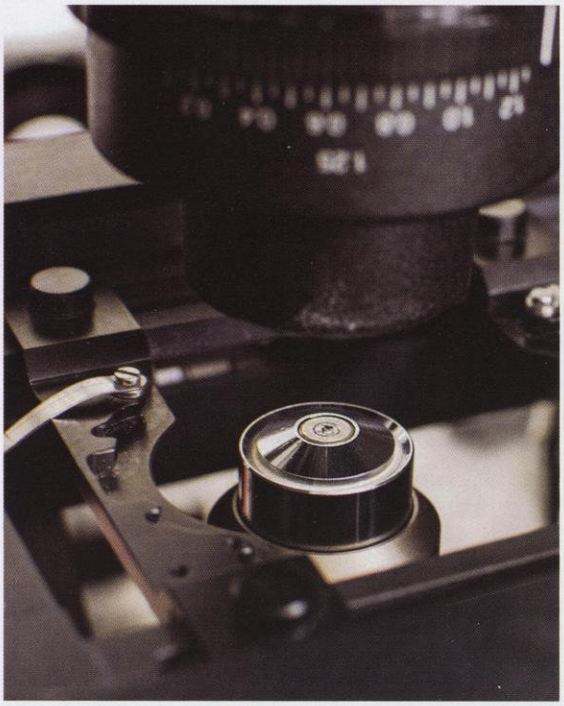
Photography by: Simon Hensen

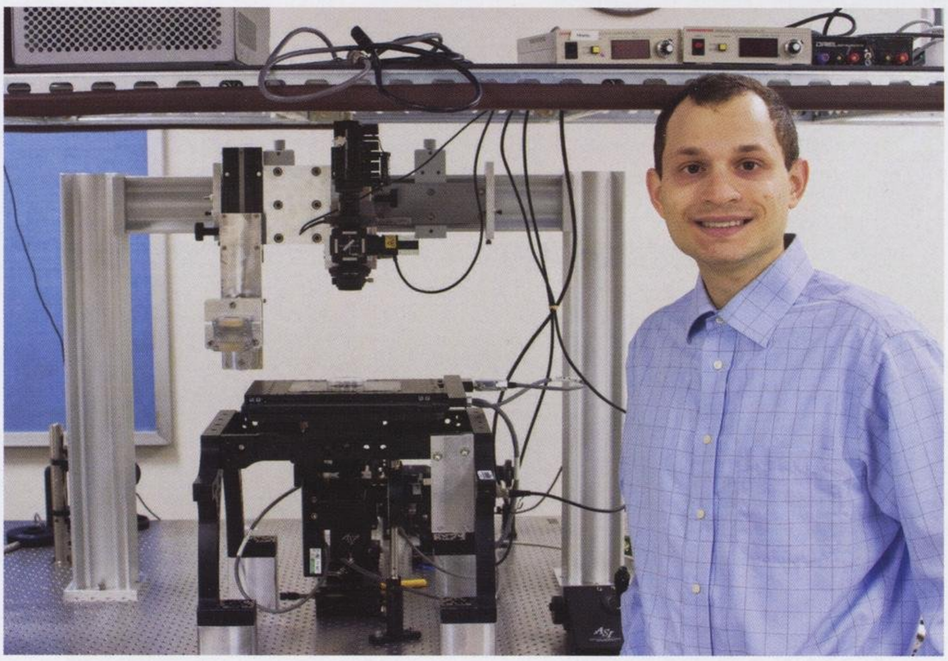
Design by: James Johnston

Cancer's Highway to Escape

UW-Madison research team studies collagen's role in cancer progression.

"This development is very scary, and very powerful."
- Professor Eliceiri





Top: The CAMM automated multiphoton microscope for looking at collagen organization.

Bottom: Medical physics grad student, Michael Pinkert, with the multi-modal microscope he is working on. The microscope combnies optics and ultrasound to look at collagen organization.

Opposite: This image depicts part of the laser setup for the CAMM microscope.

The UW-Madison Laboratory for Optical and Computational Instrumentation (LOCI) directed by Dr. Kevin Eliceiri recently helped to find a link between the very protein that keeps our bodies from falling apart and pancreatic cancer. An interview with Dr. Eliceiri shed light on how one of the most important proteins in the human body is also a key player in allowing pancreatic cancer to become so devastating and malignant.

LOCI, located in the UW-Madison Animal Sciences Building, focuses on using optics and software to understand how cells behave when they are afflicted with cancer and other diseases. "The key here is paying attention to the microenvironment, which can influence cell behavior," Eliceiri says. A microenvironment is the physical and chemical area surrounding an organism or cell. For example, Eliceiri describes that his own personal microenvironment of his lab is made up "of you and my students, these lights, the ambient temperature, these desks and chairs." Studying a cell's microenvironment could facilitate better understanding of the cell's activity.

One of the major components of these microenvironments is a protein called collagen. Collagen is the most abundant protein in your body; according to Medical News Today, proteins make up about 20 percent of human body mass, and 30 percent of those proteins are collagen. In Greek, collagen means "glue" or "glue producer," which aptly names the protein because it is, in fact, the glue that holds the human body together. Collagen is found in muscles, skin, bones, ligaments, blood vessels, tendons, and more. Since it is such a prolific and multifunctional protein in the human body, collagen can be found in the microenvironment of almost any cell.

However, Eliceiri has found that this abundance of collagen works against our bodies in the progression of diseases like cancer. This was discovered in a collaboration of many labs over the last ten years studying the role of collagen in breast cancer. In particular, Professor Patti Keely's lab, located at the Wisconsin Institutes for Medical Research (WIMR), joined forces with LOCI to study the relationship between the collagen found in the microenvironment of breast cancer cells and the metastasis (growth) of a cancerous tumor.

When Eliceiri first saw an image of a tumor surrounded by collagen molecules, he says "it kind of looked to me like the tumor was trapped in a fisherman's net." In this case, the "fisherman's net" is made up of a fibrous network of collagen. "But that analogy is not quite correct because we found that rather than a net that's trapping the tumor, this net actually helps [cancer] cells escape," Eliceiri clarifies. The collagen fibers acted as an accomplice to the cancer cells and seemed to grow and align in a way that allowed the tumor to metastasize. "We found that when collagen grows around the tumor, and over time its finger-like fibers curl up and become erect and perpendicular to the tumor, allowing a sort of highway for the cancer cells to escape the tumor," Eliceiri explains.

This discovery that the misalignment of collagen helps to free cancerous cells excited Eliceiri's team and collaborators. The LOCI lab has imaging and computational tools that allow the team to precisely image and analyze this property of collagen, with an intent to characterize changes in collagen as a cancer biomarker. A biomarker is a repeatable and actionable metric for disease progression.

In this case, the hypothesis was that changes in collagen organization were linked to cancer progression. The LOCI-led team was able to show that in several cancers, including pancreatic and breast cancer, changes in collagen organization were not only linked to cancer progression, but also to the reduced chances of survival for the patient. Work is ongoing to characterize this collagen organization further and look for these collagen changes in other cancers. If scientists discover how this alignment of collagen can be prevented, then many cancers, not just breast and pancreatic cancer, can be treated more effectively.

The microscope that allows Eliceiri and his team to analyze the behavior of collagen was built in part by fourth-year biomedical engineering graduate student Adib Keikhosravi. Using this microscope, the research team can look at clinical samples without adding any stains or dyes to the collagen because collagen naturally has a glowing property. With this microscope, Eliceiri says they "can quantitate [collagen's alignment] change because when the collagen fibers start forming these highways, we can look at the angle and the area itself to see what's going on." With the help of Michael Pinkert, a medical physics graduate student, the LOCI team looks at collagen on many different spatial scales through Pinkert's new imaging instrumentation that is being built in collaboration with other UW engineering professors. Eliceiri stresses the brilliance and drive of the students on his team, joking that "everything is done by the students. I just talk about it."

Finding that one of the body's most important proteins can morph into something that can make you sick is "very scary, and very powerful." The goal of Eliceiri's team and others on campus is to determine whether this collagen biomarker is in other cancers in order to build more information. This will allow researchers to compare these morphologies and find trends in cancers, which will ultimately contribute to developing new therapies for cancer treatment. By discovering collagen's dark side, scientists and researchers can find new ways to treat and ultimately cure cancer's.

Institutes for Medical Research (WIMR), joined forces with LOCI to study the relationship between the collagen found in the microenvironment of cancer cells and the metastasis (growth) of a cancerous tumor.

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This discovery that the misalignment of collagen helps to free cancerous cells excited Eliceiri's team. The LOCI lab has an imaging tool that allows the team to precisely image and analyze this property of collagen with an intent to pinpoint collagen's biomarker. A biomarker is a measurable substance present in the protein when certain infections or diseases like cancer are present. By pinpointing collagen's biomarker, the biomarker can be searched for in other cancers to see if collagen plays a role in other cancers as well. If scientists discover how the misalignment of collagen can be prevented or stopped, then many cancers can be treated more effectively, not just breast and pancreatic cancer.

The microscope that allows Eliceiri and his team to analyze the behavior of collagen was built by fourth-year biomedical engineering graduate student Adib Keikhosravi. Using this microscope, the research team can look at clinical samples without any stains or dyes to the collagen because collagen naturally has a glowing property. With this microscope, Eliceiri says they "can quantitate [collagen's alignment] change because when the collagen fibers start forming these highways, we can look at the angle and the area itself to see what's going on." With the help of Michael Pinkert, a medical physics graduate, the LOCI team looks at collagen on many different scales through Pinkert's new imaging instrumentation. Eliceiri stresses the brilliance of the students on his team, stating jokingly that "everything is done by the students, I just talk about it".

Finding that the very protein that is one of your body's most important can morph into something that can destroy you is "very scary, and very powerful." The goal of Eliceiri's team and others on campus is to determine whether this collagen biomarker is in other cancers to hopefully build more information to compare these morphologies and to find trends in cancers to develop new therapies to treat cancer. By discovering collagen's dark side, scientists and researchers can find new ways to treat and ultimately cure cancers.

Written by: Nena Nakum

Photography by: Heather Shumaker

Design by: Patricia Stan

Recharging: One Step at a Time

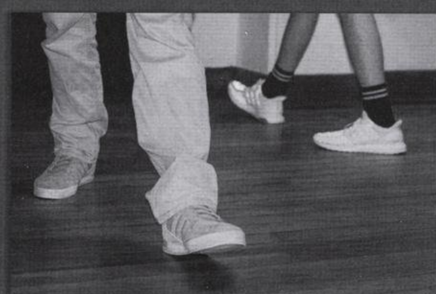
New triboelectric floor panels can harvest the energy of human movement.

Imagine charging your iPhone and powering your lights with a stomp of your foot - no batteries or cords needed. This science fiction scenario is possible today, via the technology called mechanical energy harvesting. Finding this cutting-edge technology is not hard in Madison, as it is being perfected right here on campus in Professor Xudong Wang's Nanoscience and Nanotechnology group.

Mechanical energy harvesting is the process by which energy is derived from an external force and is the basic science that enables the relatively common solar, thermal, and wind energy technologies. Wang's group studies the natural outlet of mechanical energy harvesting, called the triboelectic effect, which is the creation of energy through the contact of two materials, such as a shoe and a floor panel.

Though many energy resources are limited, human activities that create energy, such as walking and dancing, are not. Mechanical energy harvesting has been around for almost two decades, but Wang states, "We were one of the first groups to use nanomaterials to harness to harvest environmental mechanical energy." This novelty stems from Wang's previous experience with the Forest Products National Laboratory, where he used wood materials to engineer dielectric (non-conducting) properties, and then used these materials as the functional component for mechanical energy harvesting.

In order to harness the energy, a triboelectic nanogenerator utilizes mechanical friction and contact-induced charge separation. The functional component is the floor, which is structured as two distinctive layers. One layer is more electron-repulsive, while the other is electron-attractive. When placed in contact with one another, the layers displace to create an electric potential with the applied force (in this case, from a person walking across the surface). The energy potential created from this process is stored in a capacitor. This energy can then be used to charge your phone, power your lights, or even heat an entire room.



Implementing this technology across surfaces experiencing heavy foot traffic allows for the generation of electricity from common human activities, such as walking or dancing.

This energy-harvesting process is very efficient and more importantly, has an insignificant environmental impact. Other materials used in energy-harvesting floor panels besides the wood fiber electrodes include oxides, ceramics, and sustainable polymers, none of which involve the use of scarce raw materials.

Mechanical energy harvesting is studied all over the world, and there are numerous ongoing global projects that implement this technology in roadside and railroad energy harvesting. Triboelectic surfaces can also be used for more fun applications, and can be found harvesting the energy created by footsteps and dance moves in several European ballrooms. The applications of mechanical energy harvesting are endless and are still being discovered today.

Environmental mechanical energy harvesting has a very bright and sustainable future. Soon, "smart" buildings will be able to implement triboelectic floors to replace conventional energy sources, as well as lessen the electric bill. Whether you're walking, dancing, or just breathing, this new sustainability technology can turn your daily life into an energy factory. W/E

Written by: Chris Hanko
Photography by: Cody Schwarz
Design by: Jonathan Evans

"The applications of mechanical energy harvesting are endless, and are still being discovered today. "

Science and Alternative Facts

"Alternative facts" pose a new challenge for the science community.

Today, the legitimacy of science is being attacked. This is not because of any particular hatred for science, but rather due to one of the most interesting and potentially damaging phenomenon of today's time: The rise of "alternative facts" or, to put it another way, the rise of false information distributed under the guise of legitimate facts. This phenomenon is dangerous because it makes the reality of a situation less important than the narratives people push to support their agendas.

According to Andrew Kydd, professor of political science, the source of this phenomenon is a "decades long campaign" on the part of conservatives to delegitimize the mainstream media which they view as liberally biased. It is also worth noting, though, that there is currently a divide in the Republican Party between members such as Governor Scott Walker and White House Chief of Staff Reince Priebus, and those who follow the philosophy of President Donald Trump. The Trump faction would like to continue the distribution of false and misleading information whereas the Walker faction would prefer to give the American people more legitimate news, albeit likely with a conservative slant.

It is people who follow the philosophy of the Walker faction that are showing signs of regret as they come to realize what the success of the conservative campaign against the mainstream media means for society. One example of this is Charlie Sykes, a moderate conservative who Kydd describes as a "former conservative talk show host in Wisconsin who has now kind of seen the error of his ways."

But while the delegitimization of the mainstream media is dangerous, the attack on the legitimacy of science is even more dangerous and, according to Kydd, "unprecedented" in modern society. For centuries, science has helped to move humanity forward and improve the quality of life on Earth. However, this powerful force for good is currently being put under fire, threatening the success that we enjoy in modern society. Without science, modern medicine wouldn't exist and life expectancies would be decades shorter. Without science, smartphones would have never come into existence. Effectively, we need science to thrive as both individuals and as a species.

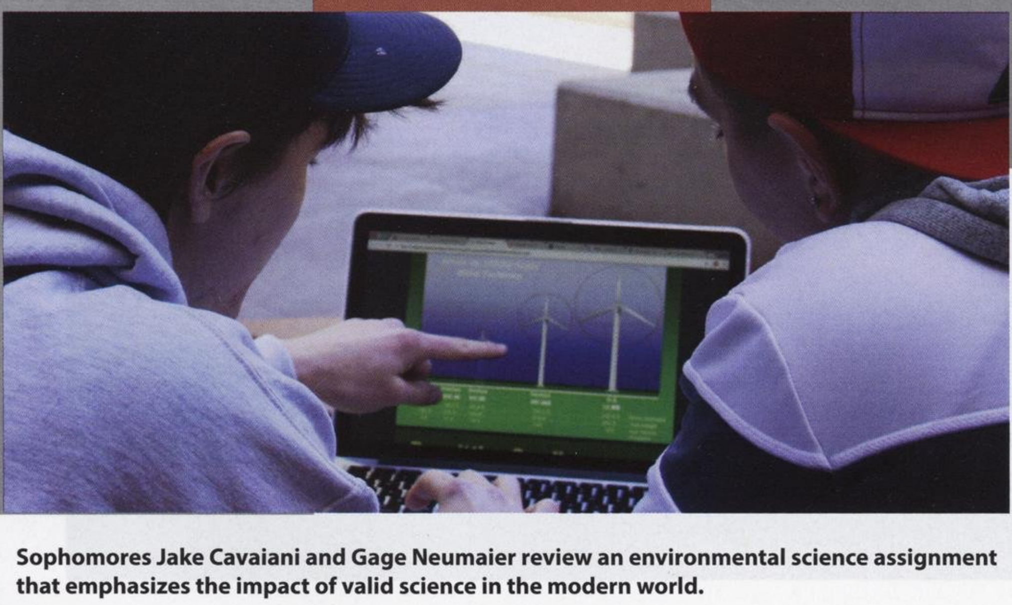
One of the most controversial conclusions to come from science is the realization that humans evolved from other species and that we continue to evolve. Evolution is an example of a scientific conclusion that clashes with long held beliefs. Science, however, is unconcerned with beliefs and is instead a process by which the world around us is explained. This means that scientists constantly scrutinize unscientific beliefs in order to discover the truth. In the case of evolution, scientists rejected the belief that humans were created in the same form as they exist today. But by doing this, the scientific community put themselves at odds with the common beliefs, and people do not like to have their beliefs challenged; it causes cognitive dissonance and some people stick with what familiar ideas rather than change their beliefs to fit the evidence. They embrace what has been shown to be misconception and delusion in order to keep their minds at peace.

Another more contemporary example of a hotly contested scientific conclusion is the existence and human causality of climate change. One of the main reasons for people not believing in climate change is largely the same main reason for not believing in evolution. That is, it causes cognitive dissonance due to the difference between traditional understanding of the weather and climate, that humans have no effect, and new claims scientists make about how and why the climate is changing. In addition to this, climate change is something that is relevant in today's society. Fighting it involves people making sacrifices and letting go of things, such as their gas-powered cars, to which they have grown attached. This makes people even more likely to stick with their beliefs when the cognitive dissonance strikes, since they may not want to make sacrifices or face the insecurity of potentially losing their jobs in energy related fields.

According to Kydd, scientists have done nearly all they can to try to persuade people that climate change is real and that it is caused by humans. He believes that scientists should not try to argue climate change any more than they already do, as it would reinforce some conservatives' conception that science has a liberal agenda. He also believes that the denial of climate change is unlikely to last forever because eventually, the facts and alternative facts will be too different for the alternative facts to survive. In other words, the facts will become inescapable. As he says, "what happens when we get tarantulas in Wisconsin?" At the same time, he does acknowledge the possibility that the change will be so gradual that perpetual denial could be possible.

When asked about how the science community should try to fight the rise of alternative facts, Kydd suggests that the main battleground is in the classroom. He believes that by teaching kids from a young age the value of science and how it works, there would be less people who ignorantly condemn it as false propaganda. People would understand that science is a field built on the benefits of criticism and improvement rather than on the dogmatic belief of certain ideas or concepts as true. In other words, the most effective way the science community can combat the rise of alternative facts is to teach people what science really is.

Written by: Connor Welch
Photography by: Beth Enright
Design by: Julia Mauser



Sophomores Jake Cavaiani and Gage Neumaier review an environmental science assignment that emphasizes the impact of valid science in the modern world.

Landscape

Musée d'Orsay | Kye Hanson

Category Winner

Schwabacher's Landing | Paul Scharlau

Runner Up

Still Life

Fall | Keith Lyster

Category Winner

Duluth Pack Rests on Shores of Charleston | Sylvie Weintraub

Runner Up

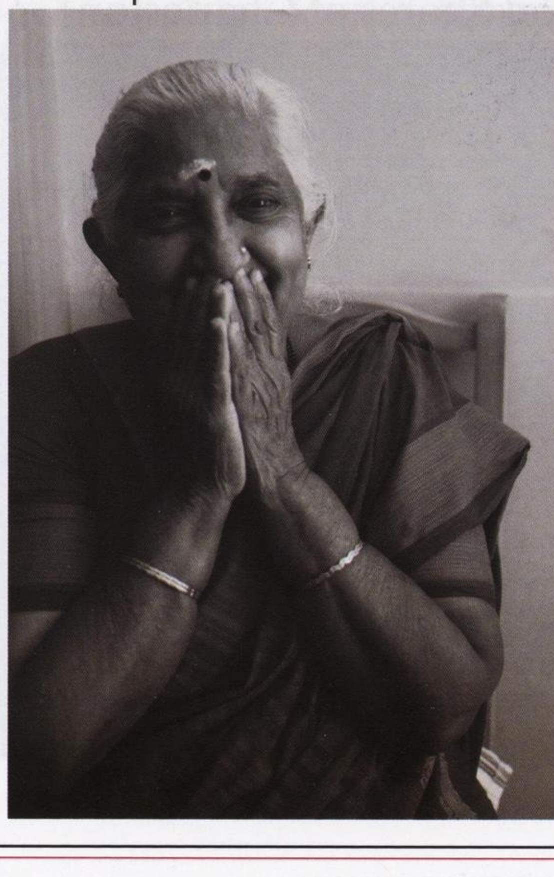
Portrait

Memoirs of Geisha | Nanicha Subhanka

Category Winner

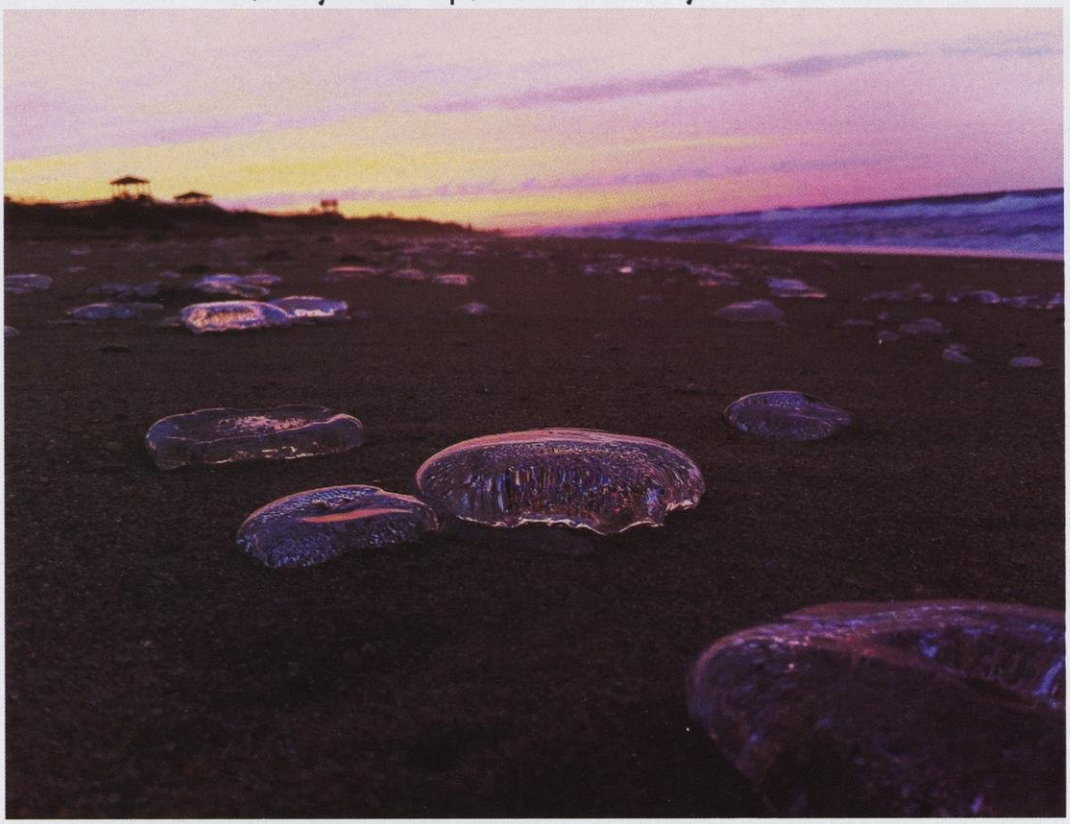
Youthful Chuckles | Rasika Ramanathan

Runner Up



Miscellaneous

Sunset with Jelly Fish | Josh Emory



Category Winner

Snowy Egret | Alec Schultz

Runner Up

The Wisconsin Engineer's

9th Annual Photo Contest

Bucket List Alert: Solar Eclipse 2017

In August 2017, a total solar eclipse will be visible from the US for the first time in over 30 years.

In 1918, the year better known for the end of World War I and a raging influenza pandemic, a total solar eclipse traversed the United States from coast to coast. Now, 99 years later, Americans will finally get another chance to experience one of nature's most awe-inspiring displays. On the morning of Aug. 21, 2017, a total solar eclipse will travel across the United States from Oregon to South Carolina. Along the way, it will pass over thousands of cities, towns, and parks, giving millions of people the chance to cross "viewing a total eclipse" off their bucket lists.

Dr. James Lattis is the director of UW Space Place, the outreach and education center for the UW-Madison Astronomy Department. Lattis cleared up a common misconception about the rarity of solar eclipses by stating, "The appearance of a total solar eclipse at a specific point on the Earth is the rare thing, not the eclipse itself." To better clarify: Total solar eclipses, which occur when the moon passes between the sun and the earth and completely covers the sun, are only visible from a small area. However, partial solar eclipses, where the moon covers only part of the sun, are relatively common and can be seen across a wide area. The defining characteristic of total solar eclipses is that they are only visible in a narrow range of about 100 miles wide. The last time a total solar eclipse occurred in the United States at all was in 1979, but it has been since 1918 that the path of totality has stretched from Atlantic to Pacific. Observers will get about two minutes of totality this year.

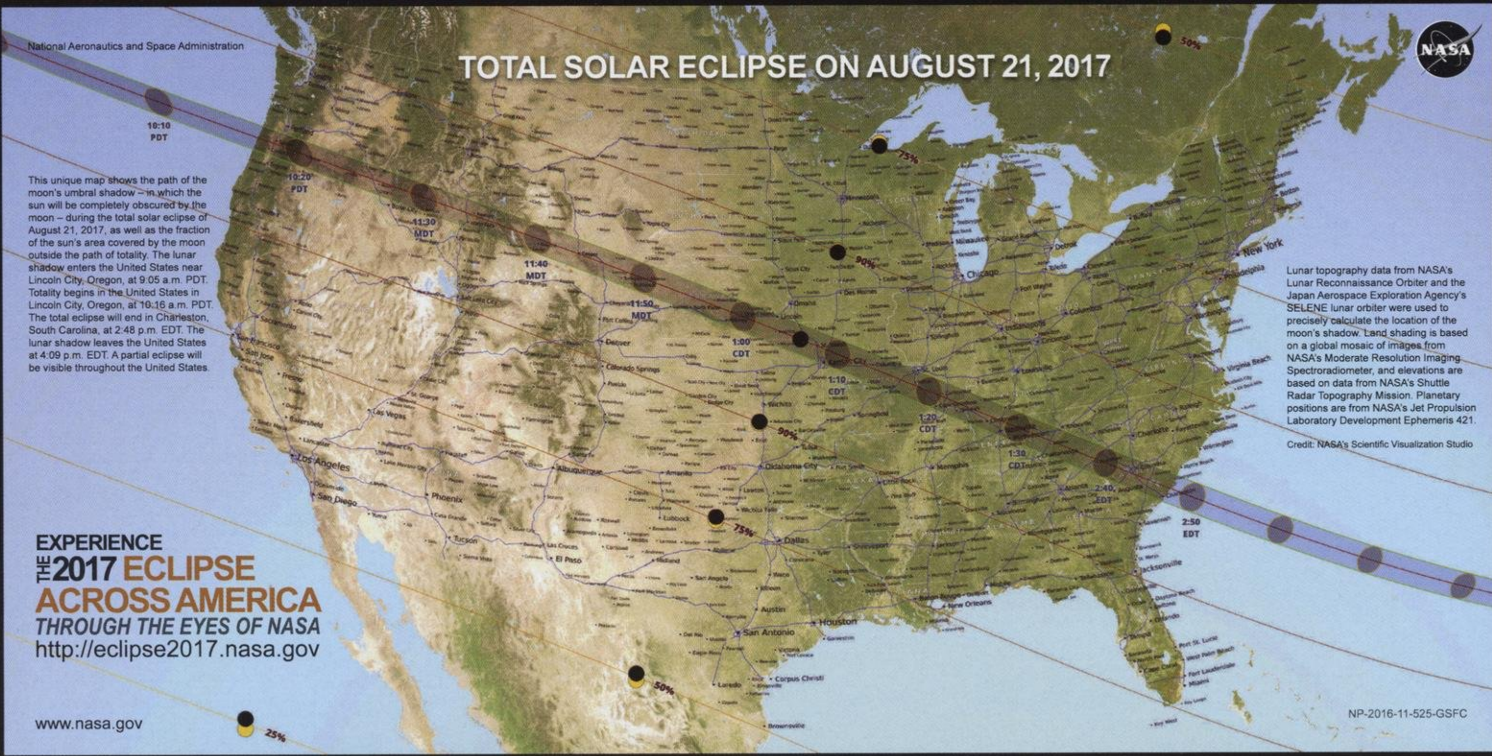
Total solar eclipses get much more attention than the more common partial eclipses, as they are far more dramatic. When situated in a broad viewing area during a total eclipse, an observer can watch the shadow of the moon race across the landscape. Lattis likens this to "a science fiction movie." When the shadow reaches the viewing point, shadow bands, which are light and dark bands, are painted across the landscape. This phenomenon continues as temperatures drop sharply once the area is covered in sudden darkness. At the abrupt arrival of nighttime conditions, birds and other animals behave strangely. Looking around, there is twilight circling the entire horizon. Higher in the sky, stars and even planets are visible, despite it being midday. However, the most striking part of a solar eclipse is the sight of the sun's outer atmosphere, the solar corona.

> **"You can't possibly miss a total solar eclipse. It's probably the most dramatic astronomical experience that I can think of."**
> **– Dr. Lattis**

The surface of the sun, or photosphere, is extremely bright. The atmosphere, or solar corona, is orders of magnitude dimmer and can only be seen during a total solar eclipse. "Even in a partial eclipse that's 99 percent covering the surface of the sun, the sunlight is still extremely bright," Lattis says. "There's enough of it that the atmosphere never gets dark and you can't see the corona." In the absence of the photosphere, the solar corona is bright and vivid. According to Lattis, in a total solar eclipse, "photographs can't really capture the bright and dark detail." It's truly something that must be seen in person.

The solar corona is not just mystifying to casual observers; it still has many secrets astronomers have yet to unlock. As the atmosphere of the sun extends away from the surface, it increases in temperature, from a few thousand degrees to a few million. This is counterintuitive; generally, things get colder further from a heat source. Solar eclipses are an important time for astronomers to study why this occurs. "There is an interesting physics going on there in that plasma environment that we have yet to understand completely," Lattis says. Although astronomers at UW-Madison are not currently participating in the ongoing research on the solar corona, they were once heavily involved, back when solar eclipses were used for a wider range of observations. Before advances in astronomy, solar eclipses were used to search for undiscovered planets near the sun, and UW astronomers partook in "eclipse-expeditions" in the early 20th century in the unsuccessful search for a planet closer to the Sun than Mercury.

Lattis has been in the path of two solar eclipses in the past. On one occasion, it was cloudy and rainy, but it still got noticeably darker during the



eclipse, even through the clouds. However, that didn't compare to the second time, when he was treated to a perfect view of the total eclipse. He describes it as "absolutely astounding," and that "you can't compare it to anything." Lattis says other astronomical events, like meteor showers, "might be fairly subtle," but "you can't possibly miss a total solar eclipse. It's probably the most dramatic astronomical experience that I can think of." Lattis plans to drive down to Kansas for this eclipse and certainly is not alone in his pursuit. Many people, especially enthusiasts called "eclipse-chasers," plan years in advance for solar eclipses. It's not uncommon for these eclipse-chasers to book accommodations in multiple locations, waiting for the big day to determine which spot will have fairer skies. The United States' roads and highways will make this eclipse particularly accessible; in contrast, many total eclipses are only visible from the ocean or remote areas of the earth.

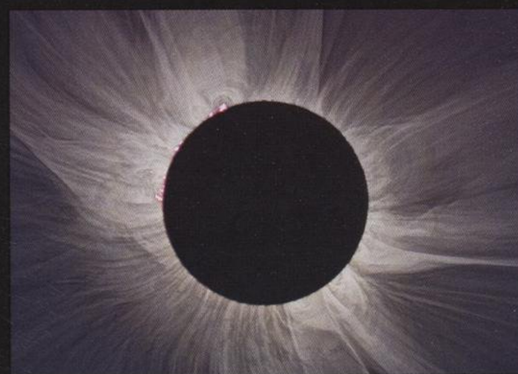
It's recommended that those interested in viewing the eclipse make travel plans as soon as possible - camp grounds and hotels near the path of totality have been filling up for quite some time. There are many public events occurring along the path of totality, and Lattis expects it to be a "huge bonanza for science outreach in the United States" Whether in the path of totality or not, it's important to protect your eyes during a solar eclipse. Looking at the sun is always dangerous and it is only during the brief period of totality that it is safe to look at it unfiltered. In Wisconsin, there will be no period where it is safe to view the eclipse directly. However, there are ways to safely observe a partial eclipse. Sun viewing filters, number 14 welder's glasses, or pinhole projection devices can all be used to observe the partially-eclipsed sun. The UW Space Place recently ordered several thousand sun-viewing filters in anticipation of local demand. Lattis also advises against using equipment to view the sun; concentrated solar rays can easily damage cameras, telescopes, and binoculars.

The 2017 "Great American Solar Eclipse" promises to be a breathtaking sight. Anyone who is able should try to witness it. But fortunately for those unable to get to the path of totality this August, the United States will be graced by another total eclipse relatively soon, in 2024. However, as the experience of Dr. Lattis shows, it's a good idea to plan to attend both. Astronomers can guarantee when and where a total solar eclipse will occur, but they can't guarantee it won't be cloudy.

Written by: Eric Fleming

Photography: Images courtesy of NASA

Design by: Patricia Stan



Top: Plan your trip to see the solar eclipse - while you may not be in the "path of totality", a majority of the U.S. will be able to see at least a 75 percent eclipse.
Bottom: Composite Image of the sun during a total solar eclipse.
Images Courtesy of NASA.

The Artificial Eye:

Advancing Optics through Bio-inspiration

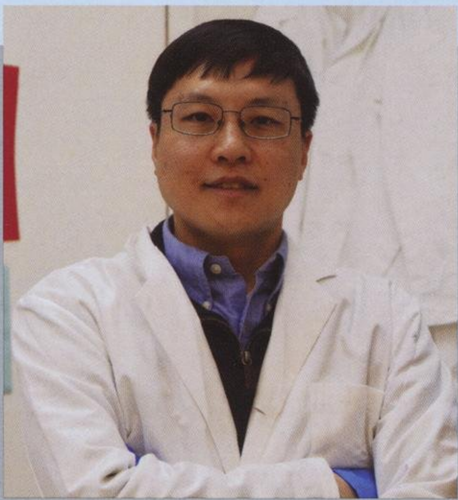
Research in optical imaging is proving nature's significant role in scientific and technological advancement.

Have you opened your Snapchat lately? Analyzed the structure of a bacterium in a laboratory? Taken down notes projected on a wide screen? Through these seemingly menial tasks, you witness the significance of optical imaging systems in our daily lives. Beyond these daily applications, optical imaging is utilized for night vision, astronomy, and nanoscale observation. Even with significant milestones in the world of optical imaging, researchers at UW-Madison are devising ways to improve the efficiency and structure of the systems, with their latest focus being an artificial eye that can see in the dark. The retinal structures of various organisms, which are the quintessential optical imaging systems of nature, have proven vital to their research. Hence, as observed in other scientific advances, the concepts of biomimicry and bio-inspiration have been the backbone to the artificial eye project.

According to Hongrui Jiang, a UW-Madison professor of electrical and computer engineering, "90 percent of the information we collect is visual," emphasizing the importance of optical imaging. To accommodate this necessity, the world of optical imaging has undergone significant advances and evolution. For instance, the camera, which was invented in the seventeenth century, has dramatically progressed in terms of compatibility and portability. Aside from size, the camera's light sensitivity and resolution are improving at an incredible pace; telescopes can scan galaxies and infrared lighting gives us a glimpse beyond the surface of what our eyes can perceive. Nevertheless, as the world of science and technology perpetually advances, there are a few factors in optical imaging that could use some level of improvement.

Infrared lighting has been useful for vision in areas of low light, but the lighting only responds to warm objects (which can be rare in cold climates). The image produced is not ideally clear either. Devices such as flashlights and headlights have a range limitation with their beams. With regard to limitations of common optical devices, Jiang notes that optical devices typically have an imager which captures photons and converts them to electricity. For a clearer image, the number of photons collected needs to be at its maximum. This is not the case under shortages of light. In the case of a camera, to compensate for the lack of photons, the exposure time is lengthened accordingly. The camera is set up steadily to minimize movement and the shutter is left open for a specific amount of time to enable projection of a sharp image on the receptor. While efficient, the technique can become problematic when the object of interest is in motion, creating a blurry image.

To correct this problem, researchers at UW-Madison are currently working to enhance the photosensitivity in optical imaging systems. Jiang, alongside colleagues from various engineering departments, has spearheaded work on the Bioinspired Photosensitivity Enhancer (BPE). The main goal of the BPE project is to optimize the collection of photons in areas of low light. At a fixed shutter speed, a sharp image would be produced with minimal chromatic aberration (a common optical problem that occurs when a lens is either unable to bring all wavelengths of color to the same focal plane, and/or when wavelengths of color are focused at different positions in the focal plane). Jiang researches the two ways of minimizing chromatic aberration by using the intricacy of optics to enhance photosensitivity and by electric amplification of the limited photons into greater optical signal. The major downfall of the latter is the extravagant amount of energy required, which is not only costly but detrimental to the environment. Thus, the objective behind the BPE is the creation of an "artificial eye" that optimizes the gathering of photons through the propagation of optical waves while maintaining minimal power consumption.



"The retinal structure of the elephant-nosed fish is an example of bio-inspiration… not many other animals have that structure… collection of photons at a specific wavelength can be optimized… in areas of low light," -Professor Hongrui Jiang

As mentioned before, a clear majority of Jiang's work on the artificial eye has been dependent on the crucial role of biomimicry and bio-inspiration. While the two concepts are significantly related, their distinction lies in how nature is used in the engineering of artificial systems. Biomimicry seeks sustainable solutions to human challenges by emulating patterns in natural systems. In Jiang's work, the concept of biomimicry has been manifested by the fact that it is imitative of retinal structures of decapods (such as lobsters and squid) and the compound structure of insect eyes. Like insects, decapods have compound eyes but are distinguished by the fact that they consist of multiple mirror tubes rather than lenses. Hence, their focusing mechanism is based on reflection rather than refraction of light. Jiang's research focused on the replication of this retinal structure as one of the advancements in the artificial eye project.

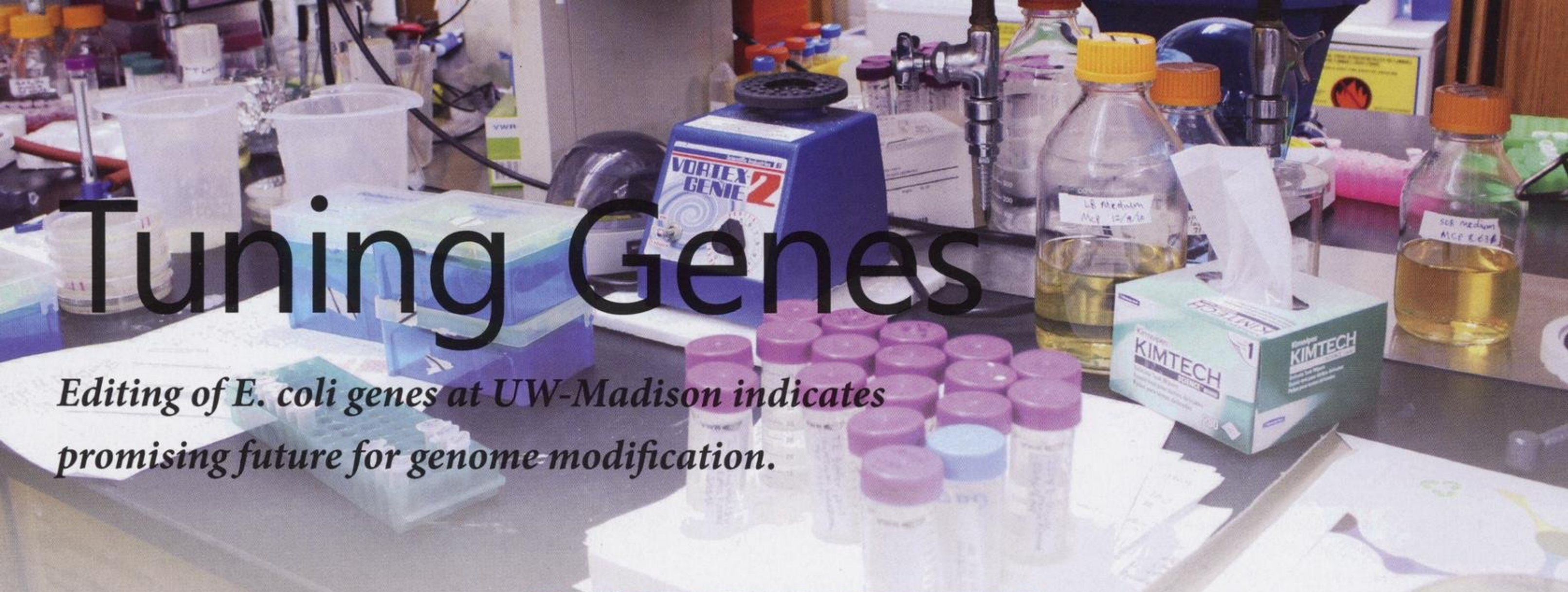
Bio-inspiration, on the other hand, takes patterns from nature and, rather than replicating them, focuses on their most important traits and modifies them for better efficiency. The latest application of bio-inspiration in Jiang's research has been with the elephant-nosed fish. Rather than simply mimicking the retinal structure of the fish's eye, Jiang and his team used its most fascinating features and attempted to integrate them in the fabrication of their latest artificial eye. The retina of elephant-nosed fish has a microscopic array of funnel-shaped parabolic cups whose walls are lined with nanophotonic crystals. They efficiently collect light (red light in this case) and guide it along the side of the funnel to the photoreceptor. This rare retinal anatomy provides clear vision for the fish even in the murky waters of the Niger River Basin. The challenge for Jiang and his team was replicating the structure while modifying it to absorb more than just red light, as human vision requires a wider range of wavelengths. Another challenge was fabricating the parabolic cups on an accurately controlled nanoscale; the process lasted a few years. The next step was laser ablation to transfer the array of cups into a hemispherical dome, a shape efficient for the minimization of chromatic aberration. Hence, the BPE was created and incorporated into small imagers which composed the new kind of artificial eye.

Currently, Jiang and his team are shifting their focus to finding specific applications of their completed artificial eye, which will surely revolutionize optical imaging. Better images could be achieved in low-lit areas which can potentially improve security systems, scientific observation, and night photography. The next time you are trembling in the dark, simply envision that someday seeing clear images in low light will be possible thanks to such mind-blowing research on campus.

Written by: Jemimah Mawande

Photography by: Therese Besser

Design by: Suzanne Kukec



Tuning Genes

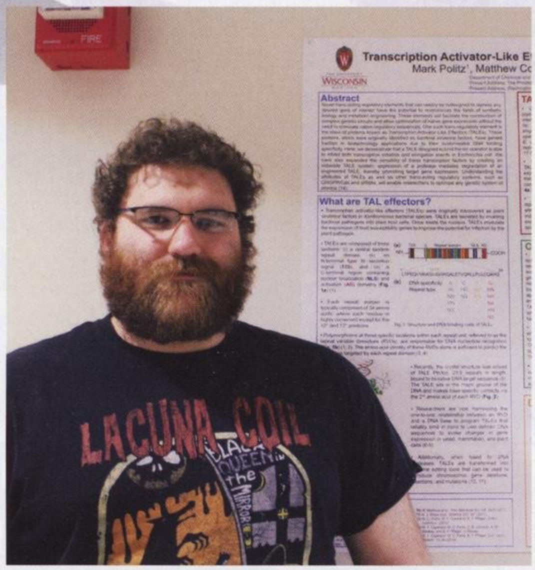
Editing of E. coli genes at UW-Madison indicates promising future for genome modification.

As human scientific knowledge becomes broader and deeper, we are more able to mimic and edit aspects of nature in engineering. One branch of biological engineering, synthetic biology, focuses specifically on this process of recreating or altering biological systems, often to achieve a human end. Along with this biological engineering comes the controversial but only recently realizable topic of genetic engineering. The species to which gene modification can be applied ranges from crops to humans, but one particular group may hold the key to creating more efficient energy and other wider applications: Bacteria.

At UW-Madison, a team of biological engineers under the direction of Professor Brian Pfleger has been conducting research that is one facet of the quickly expanding field of synthetic biology. Within the labs of Engineering Hall, these engineers are using transcription activator-like effector (TALE) proteins to alter the genes of E. coli in order to render their natural cell processes more efficient for human use.

The discovery of TALEs, is "a traditional scientific story, where people had no idea what they were stumbling on," says Mark Politz, a lead member of Pfleger's team who is currently working on a postdoctoral program at UW-Madison. While studying plant pathogens, a group of researchers noticed that when infected with a certain bacteria, the plant would have an unpredicted, extreme response. Instead of the expected bacterial infection, the plant cells would terminate themselves immediately to prevent a successful takeover. What these scientists witnessed was the result of what Politz calls an "evolutionary arms race between the plant and these bacteria."

This phenomenon is caused by the plant's reaction to the TALEs' unique modular structure, in which each region of the TALE recognizes a specific nucleotide (a structural unit of DNA) on the plant DNA and promotes disease throughout the plant. Now biological engineers are taking advantage of this straightforward nature by modifying small portions of the TALE proteins to create a new binding sequence. When E. coli are injected with these proteins, they turn specific genes on or off without having to go through the more complex process of altering the chromosome itself.



Graduate student, Mark Politz, standing in front of his poster done for the research. Top: The lab where the experiments were tested.

The ability to edit a cell's DNA in a simpler way than was possible before poses many possibilities in the fields of synthetic biology and biological engineering. According to Politz, "We are dynamically controlling gene expression in E. coli to further some end we have, which is generally making a chemical." A paper published by the team in 2016 in the online edition of "Nature Chemical Biology" provided a proof of concept in reprogramming these proteins. In this study, Pfleger and his team were able to confirm that the TALE proteins are capable of targeting and binding to certain genes, turning off their expression.

One issue that needed to be overcome by the engineers was the natural tendency of the TALE to remain attached to the host DNA, which would eventually harm the E. coli; the process would need a deactivation mechanism if it was to be viable. This was accomplished by adding a chemical signal to the cell, which causes it to produce a protease (an enzyme that degrades a protein) that cuts the TALE, rendering it unable to bind to DNA. This process is a central concept of the 2016 study, proving that the use of TALE proteins is sustainable in E. coli and is feasible for large-scale use.

The primary goal of this research is to manipulate E. coli gene expression through bacterial TALE proteins so that they convert the carbon in sugar to forms usable for humans - namely fatty acids or biofuels such as gasoline - instead of using the carbon for other cell functions. "The idea is to turn these into a tool for metabolic engineering," Politz says, as their research focuses on chemical and energy production. Now that Pfleger's team has proved the viability of the TALE and deactivation mechanism, this technique could be adapted to bacteria other than E. coli, improving crop yield, and even curing human diseases in the future.

This field of biological and genetic engineering is fairly new and experimental, and hesitance remains over the bioethics of gene modification. With modification of eukaryotic organisms now possible, thanks to genome editing technology of both TALEs and other mechanisms such as CRISPR-Cas9, modification of human genes is no longer in the realm of science fiction. "There are still discussions of using these TALEs for genetic engineering," Politz says, in reference to the future of this genome technology. As biological engineering progresses, scientists and citizens must continue to weigh the consequences of altering nature at its most fundamental level against the significance of the applications for which the technology is used.

Written by: Katlyn Nohr
Photography by: Lianne Komen
Design by: Patricia Stan

Student Org Spotlight: Formula SAE Team

On your mark, get set, go! Learn about the UW-Madison Formula SAE Team.

Every engineer dreams of watching their designs brought to life. They spend hours designing, modeling, and building to make their dream a reality. Typically, undergraduates are not given the opportunity to bring a large-scale project to completion, but the Wisconsin Racing Team is a rare opportunity for students to do just that.

Wisconsin Racing is a collegiate Formula SAE race car team at the University of Wisconsin-Madison. The team of about 30 students collectively work together to design and build a scalable race car. After building their design, these cars compete in national and international races every May and June. SAE, which stands for Society of Automotive Engineers, coordinates the annual SAE Collegiate Design Series. This event was first held in 1978, though the Wisconsin racing team began competing in 1998. Each team races car prototypes in different events to compete for points.

The points in the competition are drawn from various categories. According to Combustion Team Principal and Mechanical Engineering junior Eric Maciolek, "These competitions consist of various static events, like the business development of the team and their vehicle's design, as well as more dynamic events, like the car's acceleration or endurance." The Wisconsin Racing team has an established history, taking first at the World Championships in 2007 and placing in the top five for the past five years. When asked about the chances of winning this year's title, Maciolek is very confident. For the past few years, the championship title has been won by European teams. Wisconsin Racing, however, has a few tricks up their sleeve to bring the title back to the United States.

A big change in the organization's 2017 plan is the decision to build a fully electric vehicle along with their traditional combustion vehicle. This task demands new levels of time and effort from the team. They have had to double in size to accommodate the electric designs, and the students have spent more time seeking sponsorships from companies in order to fund their project. The task is complicated, but the team has proven capable of taking it on.

> **"It's been really interesting to watch both our combustion car and electric car come to life, side by side. This technology is where the transportation industry is moving and we're just keeping ourselves in the game."**
>
> **- Eric Maciolek, Combustion Team Principal**

"We wanted to make a lot of the components the same, aside from the obvious one that the cars need to power themselves," Maciolek says. "It's been really interesting to watch both our combustion car and electric car come to life, side by side. This technology is where the transportation industry is moving, and we're just keeping ourselves in the game."

The team right now is working day and night building both cars. Midterms and homework take a backseat when it comes to this student organization. According to Maciolek, a typical year for the team is spent designing the vehicles in the fall and fabricating in the spring. The sacrifice is worth it; in engineering an entire race car, the students in this organization have the experience of a lifetime. This expertise certainly pays off: many team members receive internship opportunities from companies in the industry. The students are also able to meet and connect with other teams around to the world to manufacture the latest and greatest vehicles. "Aside from improving my engineering skills, I've learned a lot about the non-engineer aspects of life. I've learned how to manage my time properly, stay organized, and work with a diverse group of students," Maciolek says.

As of March, the team was working on the fabrication of both the electric and the combustion cars. Thanks to their many sponsors and academic advisors, they fully prepared themselves for the May competition. The atmosphere at Wisconsin Racing is nothing but positive as students are able to accomplish the tasks at hand. It's interesting to watch a group of fully motivated individuals come together and create innovation.

"I couldn't imagine a better way to spend my time during my undergraduate career," says Maciolek. "Wisconsin Racing has given me so many opportunities, both professionally and academically. It's really a great thing to be a part of." W/E

Written by: Claire Holesovsky
Photography by: Lauren Kuzminski
Design by: Patricia Stan

Keeping Cool to Save Lives

New cooling technology developed at UW-Madison is being used to maintain organ viability in transplant procedures

Every ten minutes, a person is added to the national organ transplant waiting list. After this, the wait can become lethal, as approximately 22 people in the U.S die every day while waiting for an organ transplant. Organ transplantation is a very sensitive and complex procedure and organ preparation is a crucial step in that process. The surgeons must not only transit the organ to the location of the surgery but also conduct a backbench procedure where the organ is prepared for transplant to the patient. A key component of this process is keeping the organ at cold temperatures during preparation to best preserve its viability.

Since the 1960s, there have been some advances in organ transplant temperature control, evolving from simple bags of ice in standard picnic coolers to more advanced portable coolers with precision temperature control. Unfortunately, this advance in temperature control has not extended to the preparatory backbench procedure. Immediately before the transplant process, the backbench process happens in the same operating room as the patient. The standard setup for this is an operating pan with sterile ice. This run-of-the-mill technique has caused complications with organ vitality because of the various temperature fluctuations the organ must withstand before transplant.

> **"This project was generated from the minds of UW engineering students , and now has the potential to save the lives of countless people around the country."**

There are further complications with this method as there is no easy way for the surgeon to regulate the temperature inside the ice pan. and melting ice can cause organ transplant complications. Realizing that this low-tech organ cooling process during the backbench procedure was in need of an upgrade, University of Wisconsin Medicine and Public Health Chair of Transplantation, Dr. Dixon Kaufman, reached out to the UW Biomedical Engineering Design Program and the Morgridge Institute for Research FabLab.

In order to develop a better backbench cooling solution, this clinical problem was posed as a project for the BME undergraduate design program in the spring semester of 2015. Put to the task were four UW Biomedical Engineering Design students led by FabLab Director, Dr. Kevin Eliceiri. The senior FabLab engineers were Robert Swader and George Petry, who helped the BME undergraduate students, Annie Yang, Monse Calixto, Alex Craig, and Reed Bjork, to create a cold transfer integrated table to hold the specific organ in place and regulate the temperature with calibrated temperature control.

This new design uses thermoelectric cooling technology, which allows the organ to bathe in a cooling solution inside a metal tray. "Thermoelectric cooling involves a series of semiconductor plates," says Bjork. "When a current passes through the plates, one side gets hot and one side gets cold." The cold side of the plate is used to remove heat from the system to cool the organ and solution. To monitor the temperature of the solution, there is a temperature sensor and programmed controller monitor. These tools convey the temperature measurements back to the thermoelectric cooler, which can then adjust the cooling output based on the desired temperature. By removing the need for ice, this device allows the surgeon to easily regulate the temperature of the organ, eliminating temperature inconsistencies during the sensitive transplantation process.

"[This project] was an iterative process of communication and device implementation between the engineers and Dr. Kaufman," says Dr. Eliceiri. The resulting prototype was a unique design that implemented the original desired requirements of temperature control, but also included additional clinical advantages such as better organ position during surgical preparation and improved ergonomics for the surgeon during the often lengthy backbench procedure.

Reed Bjork, a UW alumni helping lead the development of the organ cooling device, displaying how a surgeon might interact with organs in the device.

Little to no testing has ever been done to determine the best preservation temperature for organs, though this device has the ability to change that. Recent studies have shown that warmer temperatures may help maintain the organ longer than cooler temperatures. Since this new machine is flexible with temperature changes, it can be used in further research studies and transplantation techniques to add to the knowledge of organ preservation and transplantation. According to Bjork, who is now working on this project as part of his Master's research with Dr. Eliceiri, "The device has also been used for a primate kidney transplant, which was very successful and received great feedback from the clinicians."

This project, which started from a UW physician inquiring for a solution to an unmet clinical need, was generated from the minds of UW engineering students, and now has the potential to save the lives of countless people around the country. Dr. Eliceiri notes that the outcome of this project will not only make a great impact on transplant surgery, but has also already positively influenced the training of the involved student engineers as several of them will continue on to a career of medical device development.

Written by: Erin Clements
Photography by: Alexander Fanner
Design by: James Johnston

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9th Annual Photo Contest Category winners (clockwise, from top left): Landscape, Still Life, Miscellaneous, Portrait

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