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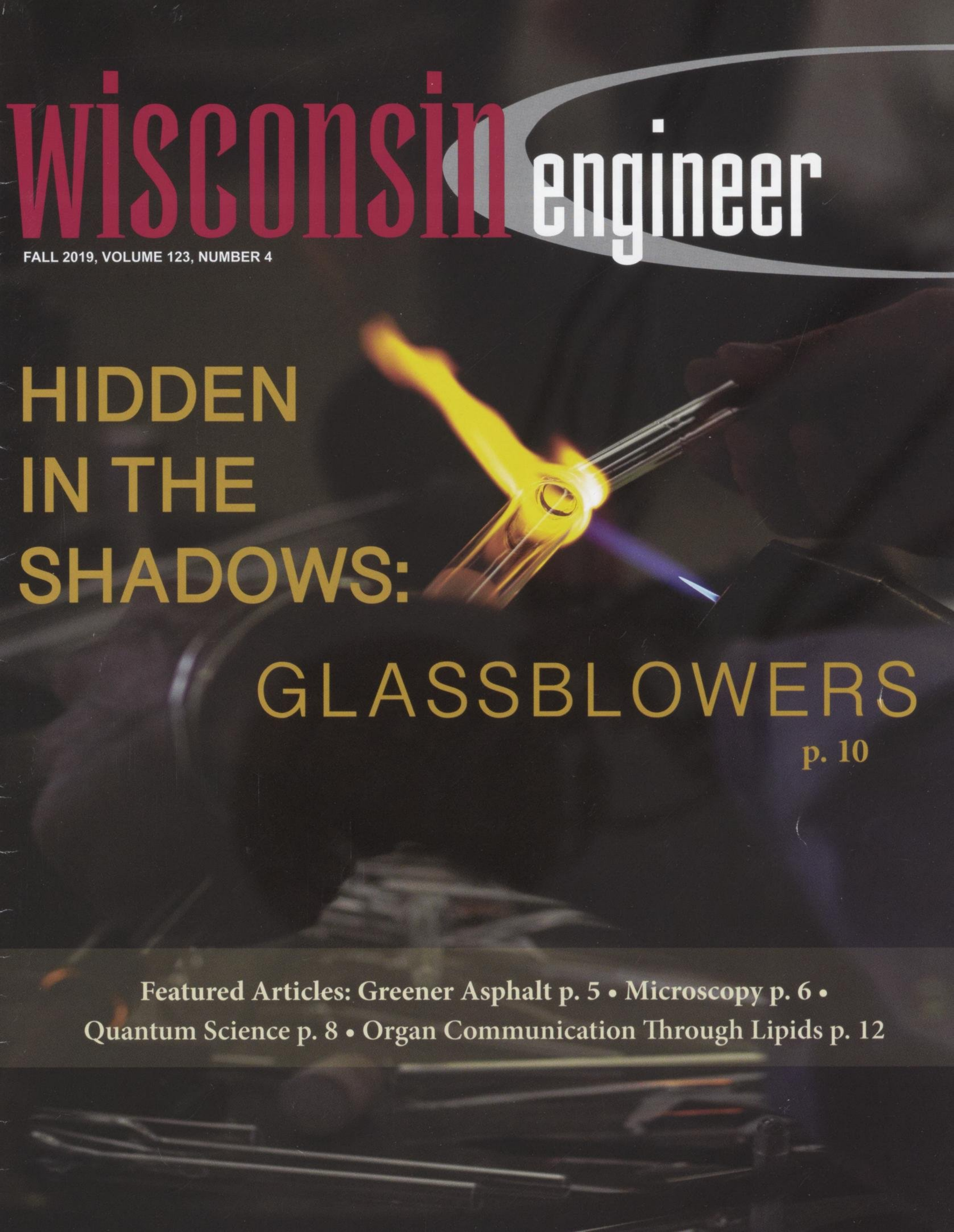

HIDDEN IN THE SHADOWS: GLASSBLOWERS

p. 10

Featured Articles: Greener Asphalt p. 5 • Microscopy p. 6 • Quantum Science p. 8 • Organ Communication Through Lipids p. 12

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Wisconsin Engineer

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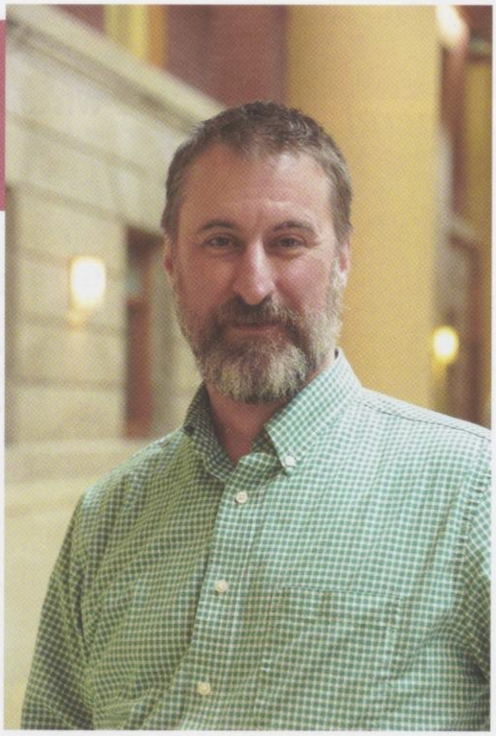
General

Cover photo by Jacobo Kirsch

Wisconsin Addiction Hotline (One Call at a Time)

A brief look into the nation's first ever addiction hotline for providers and how it's helping to change the landscape of addiction and how it's being treated



Dr. Randall Brown, a director at the Center for Addictive Disorders at UW Hospital

The struggle of addiction is a complicated and multifaceted issue and unfortunately, we still don't have all the answers. Part of the problem seems to be that the answers we do have are not yet being reached by everyone who needs them. The goal of the University of Wisconsin Addictions Consultation Service is to improve the accessibility of knowledge and tools to combat addiction.

Recognized as a national first, the University of Wisconsin Addictions Consultation Service is a daily on-call service for general healthcare providers to contact and consult with addiction specialists. The project was initiated by Dr. Randall Brown, a director at the Center for Addictive Disorders at UW Hospital and the American College of Academic Addiction Medicine, as a response to a Department of Health Services grant calling for action against substance-use disorders. The program aims to address the gaps in knowledge that general providers face when treating patients who suffer from addiction. According to Brown, "over four years of medical school, three years of residency and tens of thousands of hours, a physician on average gets exposure to about eight hours of formal education on substance use issues." Even with the eight hours of additional training needed in order to prescribe medications that treat opioid-use disorders, in this clinical setting many doctors still report feeling unconfident in their ability to handle patients in these situations. After all, to prescribe a medication is not the same as treating the underlying psychological, mental, and emotional symptoms of the patient's disease.

"Over four years of medical school, three years of residency and tens of thousands of hours, a physician on average gets exposure to about 8 hours of formal education on substance use issues."

By offering support to general providers as opposed to patients directly, this service attacks the problem of addiction in a number of unique ways. For instance, it is common for people to receive healthcare from their primary physician alone, particularly in rural communities. Specialists around their area may be scarce, expensive, or otherwise out of reach, leaving these general access points as their only option. In such a case, it is certainly in the patient's best interests that the staff at these facilities are well-equipped to deal with any of the problems that they may have, including substance-related issues.

The call service is especially prepared to help with questions revolving around the prescription of medicine. This becomes even more important as the medication route for treating addiction continues to increase in popularity. Primary physicians may also serve as a less intimidating way to take initial action and extend a treatment option to those who otherwise resist or aren't able to access more intensive rehabilitation solutions. Ultimately, if effective medication and guidance can be more widely prescribed in these general settings, it means that many more patients will be able to take advantage of these positive resources. As Dr. Brown states, "This may foster longer-term recovery or, at least, serve as a bridge that reduces substance-related harm while the patient awaits a needed, more intensive treatment resource."

The hotline is currently staffed with five licensed doctors, including Dr. Randall Brown himself, and features several other fellows in training. Most of the help provided through the service involves recommending whether a patient should receive medicine or how to otherwise assess the degree of a patient's struggle. Yet in all cases it seems to Brown that "the doctors calling in have left the calls feeling like they have a plan now, where they didn't before, and that's been really rewarding." As of right now, Brown states that most of the calls coming in center around alcoholism. However, he hopes that as more solutions and medications are developed in response to the opioid crisis, more doctors will be reaching out to seek guidance on managing that area of addiction as well.

Despite the great strides that have been made in recent years, we still have not completely solved the problem of addiction. Tools such as the UW Addictions Consultation Service, however, are making the help that currently exists more accessible. This service has already been instrumental in equipping medical professionals to best help those struggling with addiction, and hopefully continues to reach more and more of those in need.

Written by: Brianna Tobin

Photography by: Evan Birschbach

Design by: Lucas Bartel

Getting to the Heart of Predicting Cardiac Failure

Dr. Witzenburg designs models of the heart that predict how the heart will grow and change in response to cardiac heart diseases such as hypoplastic left heart syndrome (HLHS) to improve medical decision-making for clinicians.

When it comes to cardiac surgery, clinicians are under pressure to make timely and logical clinical decisions. Without any formal tools, clinicians rely on their experience and may struggle to decide not just what procedures to perform but also when to perform them. In the progression of medicine, an increasingly frequent topic of conversation is developing a more algorithmic approach to medical decision-making.

At UW-Madison, Dr. Colleen Witzenburg is researching ways to model structural changes in the heart to predict when and where surgery should be conducted in patients. Her background in mechanical engineering allows her to approach this problem by modeling the structural changes in cardiac biomaterials. "Biological material is complex in its response," says Witzenburg, "In engineering classes, we are taught to use Young's Modulus to predict stress and strain because manmade material is linear and predictable. But soft tissue does not have linear behavior; it is exponential or polynomial-like, it is anisotropic, and, in the case of the heart, contractile."

Witzenburg focuses her research on modeling the hearts of babies born with hypoplastic left heart syndrome (HLHS). This congenital disability causes babies to be born with a weak or absent left ventricle, which is responsible for pumping oxygen-rich blood to the body. When the left ventricle is nonfunctional, the right ventricle will not only perform its original task of pumping blood to the lungs, but it will also assume the role of the left ventricle and deliver blood to the entire body. As the child develops, the demand for oxygen-rich blood increases and the right ventricle becomes overworked. Consequently, the child will be at significant risk for heart failure and will have an average of three open heart surgeries before the age of four. Therefore, understanding the effect stress has on the heart both acutely and over time is critical for the survival of the child.

Comprehending the structural response of the heart to HLHS can be understood from a mechanical perspective. Witzenburg explains that biologic tissues have unique material behaviors, the most important of which is their ability to adapt to changing conditions. First, an insult or a stressor causes physical damage to the heart or changes the loading on the heart's ventricles. The heart must continue to meet the oxygen flow demands of the body, so there is increased stress and strain on the heart muscle. These increases result in the growth and remodeling of the ventricles, creating changes in thickness and dilation over time. However, as the geometry of the heart changes, the stress and strain change as well.

"Children born with HLHS often undergo multiple surgeries as they grow, but amazingly no methods currently exist to predict how a surgery will impact the shape and size of their heart."

Different scenarios can occur when the heart grows and remodels in response to overload. In one scenario the heart will grow, resolve the stimulus, and return to homeostasis. In the second scenario, however, the heart growth may exacerbate the stimulus, inciting additional growth and creating what Witzenburg describes as a "runaway situation." Understanding when and why each scenario occurs could be vital not just to clinical decision-making but also to the design of novel treatments.

While studying the structural changes occurring in the heart are important, understanding the time frame of these changes and failures is the deciding factor in the survival of patients with HLHS. An added complication of this disease is that infants grow rapidly, tripling their weight in their first year. When it comes to surgery, it is preferable that clinicians conduct operations on larger and more developed hearts. However, while it is better to wait to perform surgery until they are more fully developed, changes in the heart can cause permanent damage if clinicians wait too long. "When is the sweet spot in these two time frames?" asks Witzenburg, "Our goal is to forecast various outcomes for a patient – giving clinicians a tool that finally addresses what they care about – improvement in function for the long-term."

To better understand the time frame of these structural changes, Witzenburg hopes to project with her models when these two situations are likely to occur. In 2018 at the University of Virginia, she published a paper on a model that could predict the timing of ventricular dilation and thickening in dogs experiencing heart failure. She is especially thankful to her mentor at the University of Virginia, Jeffrey Holmes, and is happy to be adapting this model to congenital heart disease with a team of talented students at UW-Madison. They are currently focused on patients with HLHS and aim to predict the course of dilation and thickening in their hearts. Her team is using retrospective data to adapt her computational approach. One of the most significant challenges Witzenburg faces is to validate the model. She claims that a considerable part of this research is going back and forth with her model used for dogs and ensuring the parameters are adjusted to human physiology by checking against the data both for adults and infants.

Tools for better decision-making enable clinicians to be more systematic and analytical with their choices. They also make it possible for clinicians to consider larger data sets and incorporate a patient's unique background, anatomy, and physiology. Witzenburg reiterates, however, that these tools could never replace clinicians. "Congenital heart defects involve complicated changes in the anatomy of the heart and blood vessels that are unique to each child, making them among the most challenging problems in all of medicine. Our goal is to create tools that assist multidisciplinary teams – cardiologists, surgeons, imaging specialists – in deciding on the best course for each patient." The research Witzenburg and her team are undertaking will help clinicians all over the world to better succeed in treating patients with cardiac abnormalities.

Written by: Sofia Noejovich

Photography by: Jacobo Kirsch

Design by: Laura Rodricks & Erin Clements

Producing Plastics from Plants

A UW-Madison group hopes to transform the plastics industry by developing a plant-based plastic.

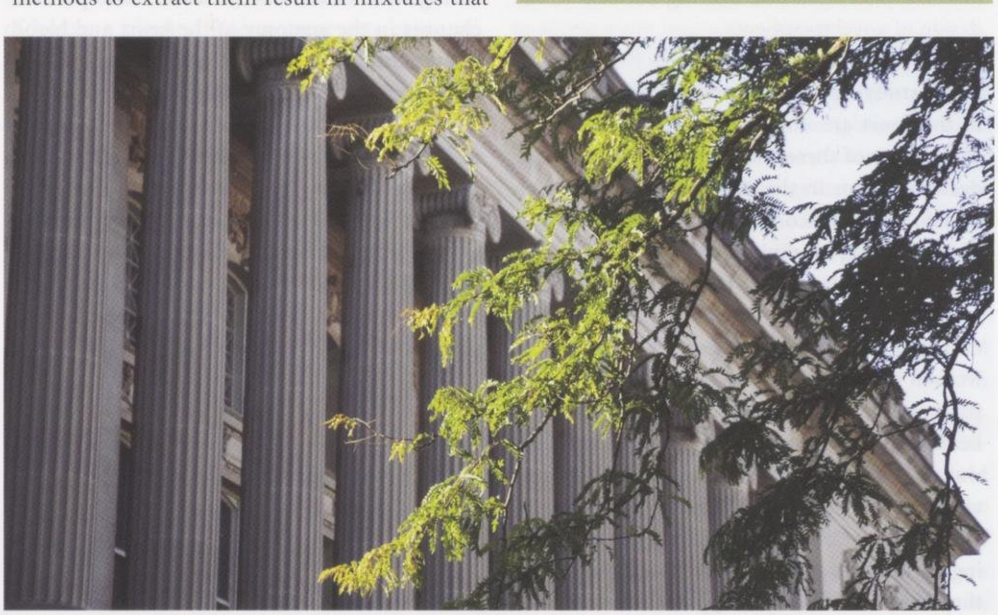
What started in the 1970s as a hunt for a "critter" that could clean areas contaminated by hydrocarbons has turned into a research project that could forever change the plastics industry. UW-Madison's Great Lakes Bioenergy Research Center (GLBRC), funded by the Department of Energy, has taken a great interest in this "critter" – the microbe Novosphingobium aromaticivorans.

Daniel Noguera, a UW-Madison professor in the department of civil and environmental engineering, along with graduate student Miguel Perez are the resident "critter" experts of GLBRC. Their original goal was to convert lignin, a renewable resource found in the cell walls of woody plants, into marketable products. "Lignin right now is not a product that has a lot of use," says Noguera, "Our goal is to make lignocellulosic (plant-based) biomass a source of fuels and chemicals as substitutes for petroleum-based products like plastic."

Apart from petroleum, lignin is the largest source of aromatic compounds – compounds that are the building blocks for a wide array of materials, including many plastics. The problem is that these aromatic compounds in woody biomass are notoriously difficult to access, and chemical methods to extract them result in mixtures that are difficult to purify. That's where N. aromaticivorans comes in. This soil bacteria grows exceptionally well when using aromatic compounds as their food source.

"We were looking for a microbe that was able to eat as many aromatics as possible and fast," says Perez. Though there are other microbes out there that can digest aromatic compounds, N. aromaticivorans is special in that it can transform a wide range of compounds into a few intermediate molecules. It also seems to eat all aromatic compounds at the same time. "That is something unique and very useful. This one is the best," says Perez. The group is using these properties of N. aromaticivorans to engineer pathways that turn the intermediate molecules into useful products. Perhaps the most attractive of these products is a pyrone-dicarboxylic acid (PDC), a naturally occurring molecule that can be polymerized to produce plastics from a renewable resource.

"We have a goal of demonstrating we can go from a tree to a product in an economically feasible way." Daniel Noguera.



"This compound could be very interesting for industrial applications," says Noguera. Apart from being a precursor for plastic that can be biodegradable, PDC-based plastics will not leech harmful chemicals into the environment like petroleum-based plastics. "PDC is a natural intermediate in metabolic pathways present in many microbes out there… if this compound leeches into the environment, we expect it to be eaten by another microbe," says Perez. In addition, finding a replacement for petroleum-based chemicals contributes to reducing our dependence on fossil fuels, thus decreasing the associated environmental effects, including greenhouse gas emissions and oil spills.

In the next step of their research, Noguera and Perez hope to improve the yield of PDC from the plant-derived aromatic compounds and scale up the process to demonstrate industrial relevance. In addition, they hope to diversify the compounds that N. aromaticivorans can produce from lignin, so this discovery can have an even wider range of possible applications. "PDC is one compound, but the idea is we can use one microbial chassis as the tool to make as many industrially relevant compounds as we can, from lignin - a renewable resource," says Perez.

Noguera, Perez, and their group recently published their work in the journal Green Chemistry. Their article was later highlighted by the Department of Energy as an example of successful DOE-funded research. In just a few years, their work could completely transform the plastics industry by creating a sustainable alternative to the petroleum-based plastics currently in use. "We have a goal of demonstrating we can go from a tree to a product in an economically feasible way," says Noguera. "And we're not too far away" Perez adds.

Written by: Sydney Heimer

Photography by: Jacobo Kirsch

Design by: Lucas Bartel

Creating Greener Asphalt

Recycled asphalt provides a platform for a sustainable future within civil infrastructure.

The demand for an improved quality of civil infrastructure, particularly concerning cross-country roads and parkways, is encouraging global research of novel engineering solutions for a sustainable paving material. The sheer quantity of asphalt production required to maintain optimal road conditions invites an environmental burden. Because asphalt production is a major contributor to material waste, civil engineers are increasingly concerned about conserving resources in its production. The aggregate used in roads cannot be reproduced and the practice of breaking down mountains for the necessary aggregate is not sustainable. The aggregate found in asphalt roads can and should be reused as much as possible to replace existing roads.

A major advantage of using recycled asphalt mix is that the original asphalt does not need to be broken down to aggregate. As a result, the material is already prepared to be processed on-site rather than having to be hauled long distances to be disposed of. The fumes and traffic congestion created from transporting the material are inconvenient and potentially hazardous to the public. The use of existing asphalt to replace major roads could reduce the environmental impacts by limiting the transportation of materials and may also negate the inconvenient impact of construction on public traffic. According to Hussain Bahia, a distinguished civil and environmental engineering professor and asphalt expert at the UW-Madison, adding higher recycled asphalt to mixes does not reduce the life of asphalt roads and parkways, nor does it increase the amount of required maintenance. In fact, with the correct engineering, Bahia says it may be possible "to produce recycled mixes that exceed the quality of the original material."

The main obstacle to transitioning to higher percentages of recycled asphalt in the mix is the binder – the adhesive component of asphalt roads. As the binder is organic and oxidizes with time, asphalt roads become brittle and fragile as they age, losing their optimal viscoelastic properties such as durability, resistance to fatigue, and workability. To keep asphalt fresh and ensure that it performs for the duration of the road's life, a recycling agent is used to rejuvenate, or soften, the old oxidizing roads. The recycling agent is a petroleum or plant-based oil that is selected by engineers. The makeup of an optimal recycling agent is still being discussed and is hindered by the inconsistent quality definition for the agent.

Another obstacle preventing the use of recycled asphalt mix from gaining popularity in practice is that only up to 20% of asphalt can be composed of recycled material. According to Bahia, to achieve 30-60% recycled asphalt within the mix, project specifications should be updated to inform the contractors of how to specify the quality in a scientific way.

"In fact, with the correct engineering, it may be possible to produce recycled mixes that exceed the quality of the original material."
– Hussain Bahia

Ideally, drivers will not even notice a difference between traditional asphalt roads and those constructed with recycled asphalt mixes. Highway engineers can ensure that the material performs as well as the original or better. Local communities will benefit financially once asphalt roads are produced with a higher percentage of recycled material as it encourages a sustainable future for the environment. Taking advantage of existing resources will help communities by limiting their environmental impact. By informing the public of this simple alternative for a material in high demand, the acceptance and practice of implementing recycled material for international infrastructure will hopefully gain popularity and become the standard.

Written by: Sarah Gerarden
Photography by: Jacobo Kirsch
Design by: Lujain Al Jumah

FLAMINGO: THE FUTURE OF MICROSCOPY

By creating affordable, portable, and reproducible microscopy technology, Jan Huisken and his team are looking to change the way we see science, literally.

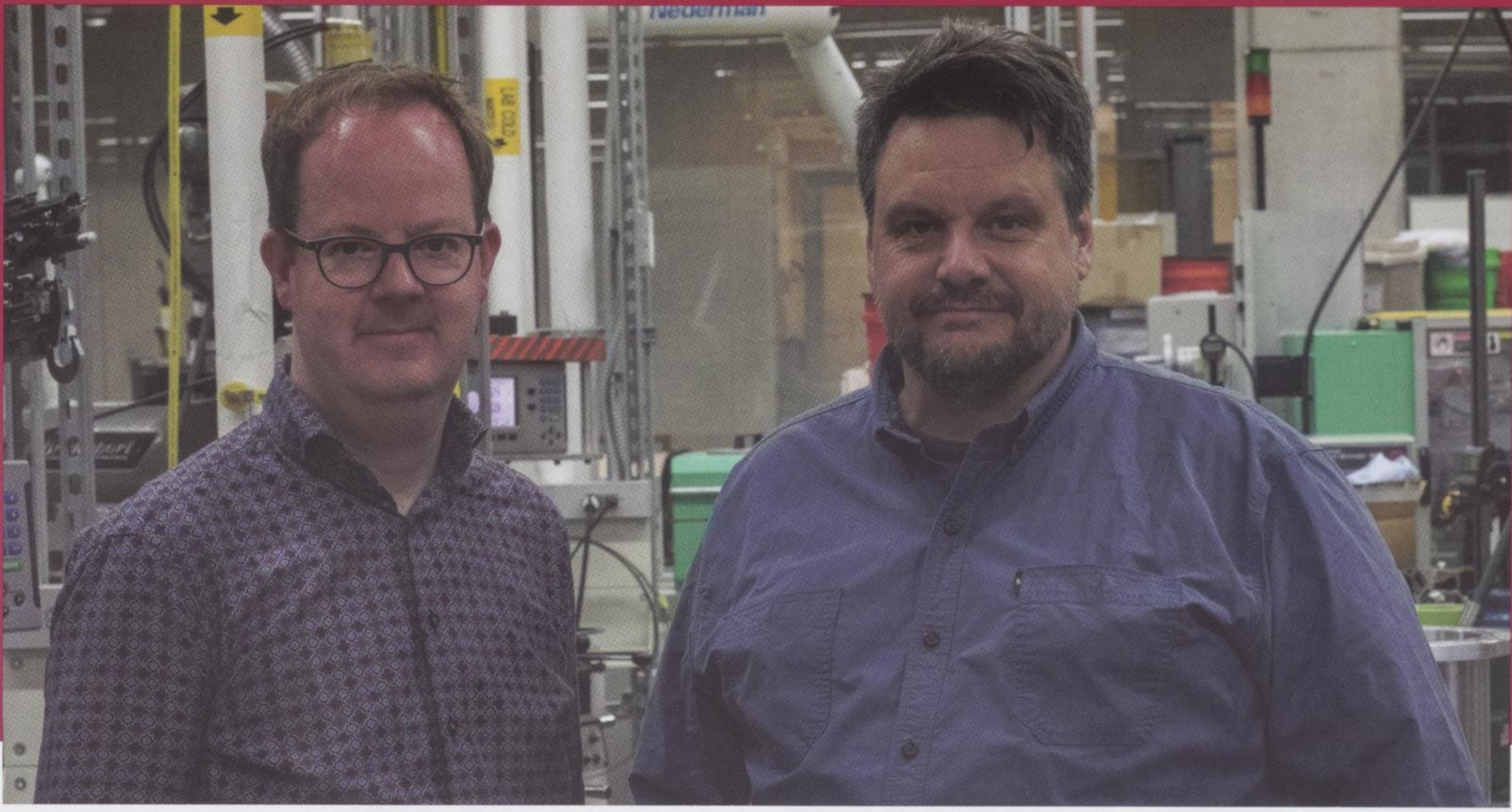
The reproducibility of experiments is an integral component of science. Without it, science is reduced to a field of 'he said, she said' and lacks the ability to foster human achievement and progress. However, the scientific community has recently been experiencing a reproducibility crisis. In 2016, the journal Nature found that more than 70% of researchers have struggled with reproducing their peers' scientific endeavors. The phenomenon has been dubbed the 'replication crisis,' and researchers are scrambling to come up with solutions. Enter Jan Huisken and his team of scientists at the Morgridge Institute for Research at UW-Madison. Huisken is the Director of Medical Engineering and the Lead Investigator of Multiscale Imaging at the Morgridge Institute for Research. The members of his team trying to tackle the crisis include Todd Bakken (Advanced Prototyping Project Engineer), Joe Li (Software Engineer), Rory Power (Associate Scientist) and Michael Weber (Field Application Specialist). "In a traditional science lab, you do scientific experiments and create equipment that cannot be replicated well from lab to lab," Huisken explains, "Flamingo solves this by taking the instruments to the samples. We create something that we use to facilitate collaboration."

The Flamingo is a light sheet microscope that utilizes fluorescence to image samples at high speed. It features extremely high resolution and typically images samples from 4x – 100x magnification. However, what makes Flamingo truly revolutionary is its portability; the technology can be packed into two suitcases. "Our newest member will be taking Flamingo around some east coast labs by himself," asserts Huisken. The portability of Flamingo enables it to foster collaboration in the scientific community. A researcher could simply email Huisken asking to use Flamingo, and the technology could be delivered within a matter of days. Usually, a researcher would need to fly themselves to an instrument, which is a hassle that has traditionally hindered scientific discovery.

"In the end, it is all about bringing the engineers and the biologists together." – Jan Huisken

If a researcher wants to purchase a commercial fluorescent microscopy device that has the same capabilities as a Flamingo, they would need to pay upwards of $300,000. Again, with the interest of promoting scientific discovery and collaboration, Huisken and his team have created Flamingo to be free for the user. Additionally, Huisken and his team are available to help with the installation and any further modifications that may be needed. Huisken and his team pride themselves on the adaptability of Flamingo. By working with researchers, they can modify the Flamingo technology to satisfy unique demands and functions. "No commercial company would listen to the users about adapting their instruments this quickly," admits Todd Bakken, a product design and technology transfer expert on Huisken's team, "…we are taking an engineering approach to scientific research."

The Flamingo design, along with any additional modifications, is meticulously kept track of and recorded to facilitate its building anywhere in the world. "For every part, we think, 'will someone else be able to replicate that system?'" states Huisken. By specifying the tolerances and dimensions of Flamingo, the reproducibility of the technology is maintained, which helps combat the prevalent 'replication crisis' in today's scientific community.



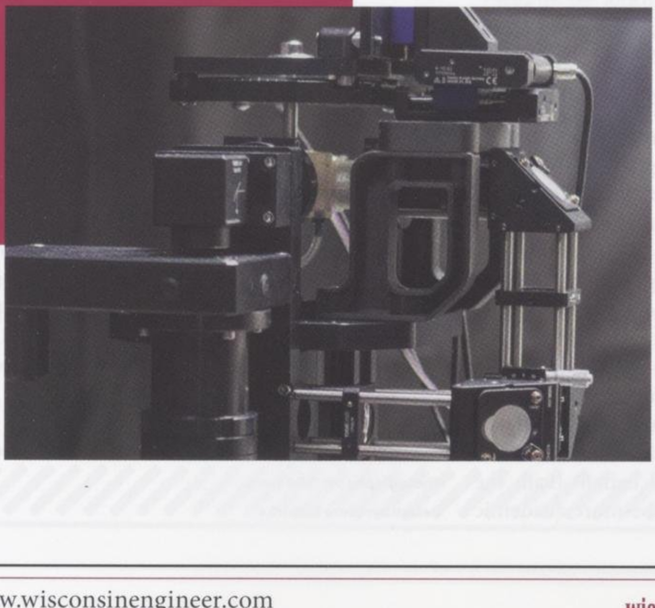
Jan Huisken (left) and Todd Bakken (right)

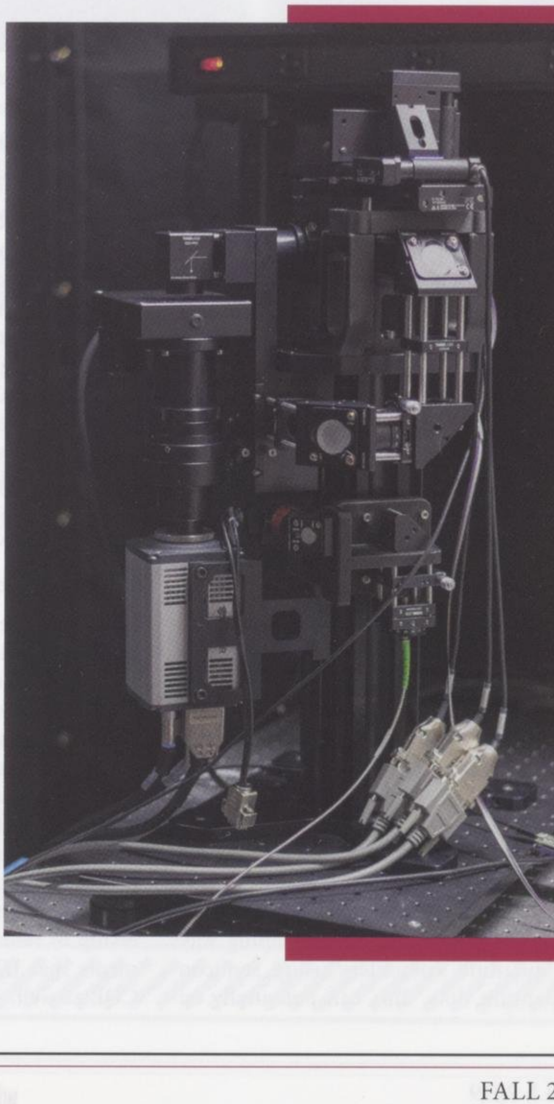
The goal of Flamingo is to encourage scientific development and collaboration by offering an affordable and accessible microscope, without sacrificing any of the abilities of a commercial microscope. "In the end, it is all about bringing the engineers and the researchers together," says Huisken. So, the next time you are at an airport and see someone carrying two suitcases, don't be so quick to dismiss it. Those suitcases might just be holding the future of microscopy.

Written by: Johnathon Brehm

Photography by: Evan Birschbach

Design by: Hannah Smoot

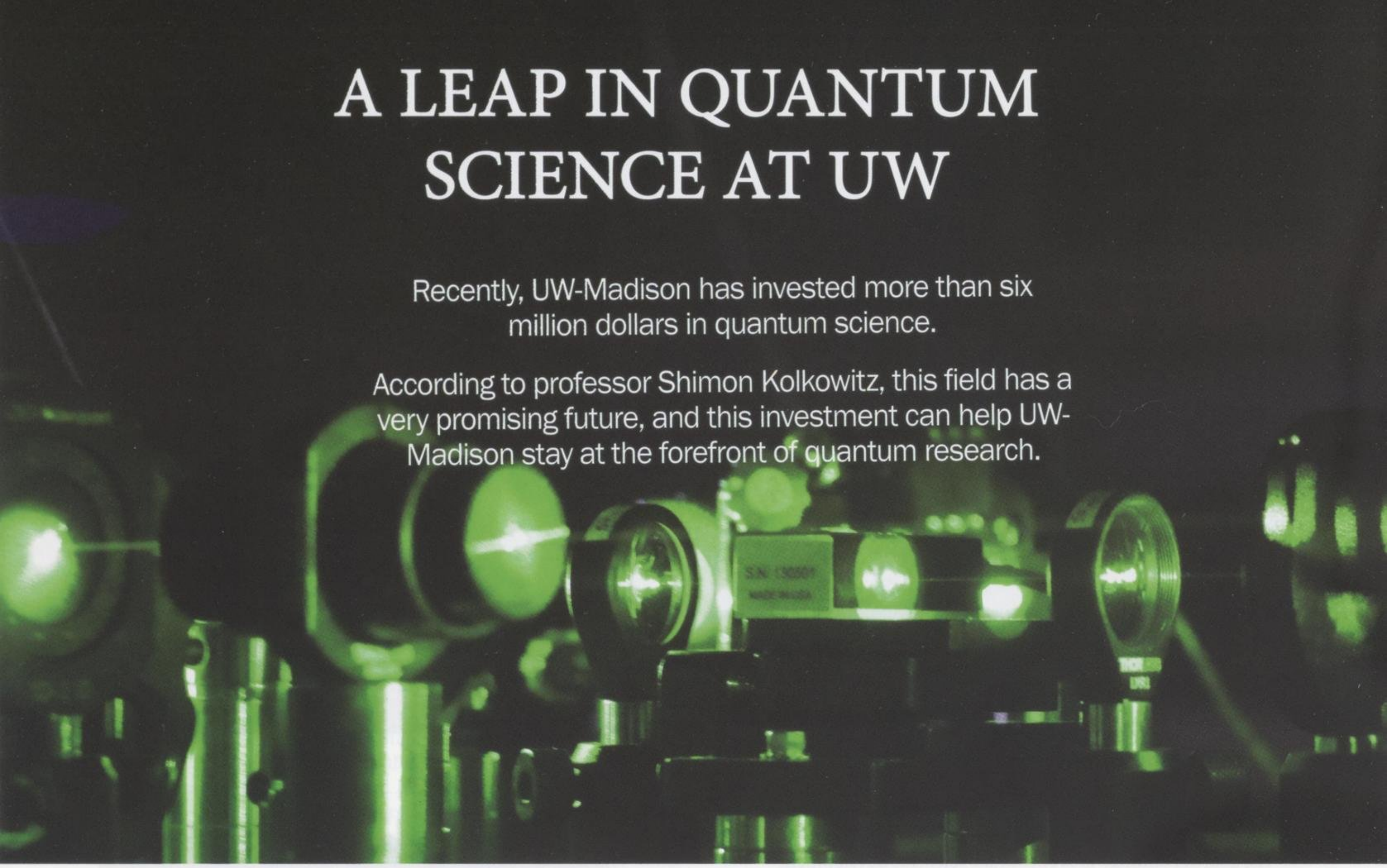




A LEAP IN QUANTUM SCIENCE AT UW

Recently, UW-Madison has invested more than six million dollars in quantum science.

According to professor Shimon Kolkowitz, this field has a very promising future, and this investment can help UW-Madison stay at the forefront of quantum research.



The application of quantum physics in different fields is becoming increasingly popular. From tech companies, such as IBM and Google, to the federal government, quantum computing has attracted investments from many sectors due to its vast potential applications. Currently researching quantum technology, UW-Madison physics professor Shimon Kolkowitz tells that this specific field—quantum computing—can lead to some great developments in pharmacy, data encryption, and material science.

Kolkowitz points out that the computers we currently use are based on classical physics, but the quantum computers that scientists are trying to build are based on quantum physics, which will use qubits rather than classical bits to perform computing. "Classical computers fundamentally are bad at simulating quantum systems," states Kolkowitz. Thus, quantum computers, which are designed with the principles of quantum physics such as entanglement and superposition, can simulate those systems and can be applied to engineering problems such as the investigation of chemical reactions and the development of new materials.

Currently, the UW-Madison physics department has invested in quantum research fields such as qubits and quantum sensing. Professor Mark Eriksson is working on developing ways to build quantum computers using semiconductor quantum dots. This can potentially enable existing classical computer manufacturers to build quantum computers. Professor Robert McDermott is researching superconducting qubits, the platform currently favored by industry in the attempt to build quantum computers, with the goal of tackling some of this kind of qubit's limitations. Professor Mark Saffman is attempting to use neutral atom qubits to perform quantum computing, which will be realized by an array of individual neutral atom qubits trapped in a lattice of light. This technique is like the one Kolkowitz is using in his research on quantum sensing. Kolkowitz is currently developing a precise atomic clock to perform the sensing. He expects the clock to be so sensitive to the environment that it could one day be useful as a precise sensor to detect gravitational waves.

UW-Madison recently joined the Chicago Quantum Exchange (CQE), solidifying the university's position at the forefront of quantum research. Joining this organization of universities including the University of Chicago, University of Illinois Urbana-Champaign, and Northwestern, along with national labs—Argonne and Fermilab—will provide UW researchers with opportunities to collaborate for more breakthroughs and the exchange of research experiences. This organization can also attract funding and industry partners, which can strengthen UW's leadership of research in this field. Kolkowitz comments that UW students will benefit from the CQE as well, since there will be more academic workshops, seminars, and conferences associated with this organization. Additionally, "there will be internship opportunities with the industry partners," Kolkowitz notes.

Due to the tremendous promise of this field, the university is also investing in training more quantum scientists and engineers. In addition to the benefits that CQE can bring to current students, the Department of Physics will be the first in the country to offer a master's degree in quantum computing. This particular program will be designed to train the quantum workforce of the next generation.

Kolkowitz hopes to spark more interest in quantum science by participating in the Wonders of Physics, an educational program started by Emeritus professor Clinton Sprott. The program features demonstrations of various physics phenomena that are especially designed for children and youth. Since the program mainly gives demonstrations of classical physics, quantum science is not addressed very much. Therefore, Kolkowitz hopes to add some of the quantum physics demonstrations to showcase this counterintuitive knowledge in quantum science so that children can learn that there is an exciting, nontraditional part of the world that is yet to be explored.

Written by: Daniel Yao

Photography by: Taha Sawar

Design by: Laura Rodricks

TAKE BACK YOUR *TRAVEL TIME*

While many people waste tons of time in traffic, new research is focused on using automated vehicles to maximize our happiness and safety in our daily commute.

Automation is a hot trend in technology, especially within the vehicle industry. One of the main purposes of an automated vehicle is to maximize people's usage of previously wasted time. Instead of being annoyed by unpleasant traffic every day and needing to commit their full focus, people can use this previously wasted time for work or for relaxation during their commute. However, an increasing number of tragedies have occurred due to the existence of automated vehicles. For example, back in May of 2016, a self-driving Tesla vehicle ran under a truck when two vehicles were both crossing the same road at high speed, ending in a fatal tragedy. Dismayed at these catastrophes, Dr. John Lee in the industrial and systems engineering department at UW-Madison decided to investigate automated driving safety and determine how people can better use their time in vehicles.

Technology can help improve the safety of driving these autonomous vehicles by determining the speed and situations of other vehicles on the road. However, not all cases are the same. According to Lee, "There are some situations where if the drivers are not brought back to the roads, they would probably die." Therefore, to ensure safety, the system must bring drivers back to the wheels at certain crucial points when the driver would otherwise put themselves or others in danger. There are several types of roads that the system cannot handle currently, such as branch roads and roundabout intersections. By assigning the tier characters to each kind of environment, the system determines whether it should request driver control. For example, when encountering a roundabout intersection, the system only takes care of entering the intersection, but the road to exit needs to be determined by the driver. If the driver is not responsive after requesting, the vehicle would be automatically directed to a safe place and stop, waiting for the driver to take back the wheel. In this way, the system does its best to ensure the driver's safety.

> **"Automated vehicle is potential to really transform lives. And it is the time. Everybody has limited time." – Professor Lee**

Currently, there are two major companies developing automated vehicles – Tesla and Waymo – but in two different user modes. Tesla, as we most commonly hear about, is mainly developing cars that can drive themselves, but still need drivers sitting in the driving position. On the other hand, Waymo is more like Lyft without drivers. Users simply book Waymo online and self-driving cars come and pick them up. Lee is doing research that collaborates between Uber and Waymo. The automated vehicles would still need drivers, but with less action needed by these drivers.

Apart from improving the safety of vehicles, this research also investigates how to improve productivity in cars. Traditional vehicles require the full attention of the driver, whereas automated vehicles could free up some time for commuters to achieve other work during the previously occupied time of their commute. Professor Raffaella Sadun from Harvard University is working with Lee to determine the economic productivity of working or relaxing in vehicles. By arranging the configuration in vehicles appropriately, we can expect to reach maximum productivity.

Lee expects that there is a potential in this research for us to change our lives. According to a survey conducted by Lee's colleague, longer time spent commuting is related to lower levels of happiness. It is the time for us to use technology to not only shorten our commutes, but also improve our happiness during these large portions of our daily lives.

Written by: Whitney Huang
Photo by: Jacobo Kirsch
Design by: Hannah Smoot & Erin Clements

HIDDEN IN THE SHADOWS

GLASS BLOWERS

Tracy Drier of UW-Madison is working hard to create an environment where people can learn new skills while having fun combining art and science.

College is a place to experience new things, and UW-Madison is a hub for such experiences. Tracy Drier, a professional glass-blower at UW-Madison, is determined to give students that "new experience" that not only allows students to learn a valuable skill, but to also have fun.

Drier is an expert in glassblowing. When people think of glassblowing, they imagine a hobby where one creates fancy and colorful bowls or paperweights with little to no real-world application. However, Drier turned glassblowing into a career where he fixes glassware and creates new pieces that can be used for scientific experiments. Typically, researchers within UW-Madison approach Drier with important pieces of lab glassware in need of repair. Having an in-house repairman for this purpose saves the university a lot of time and money.

The process for glassblowing starts with a researcher's idea which they bring to Drier, who comes up with a design. From this design, the two discuss the project's feasibility. Moving forward with the piece, Drier then takes individual glass rods with certain diameters and attaches pieces by placing the glass in a flame to transform it. While Drier works on the glass, he also blows air into a rubber tube to open the glass. Blowing into the glass in this way makes it malleable so that Drier can open up the end and smooth out the rough parts. The entire process requires precision and years of skill.

Drier was instrumental in research for the Photoelectrochemical Water-Splitting Cell that was researched by Kongki Lee, a researcher at UW-Madison. Lee's research entailed splitting water molecules into hydrogen gas and oxygen gas. Drier made the device while Lee instructed him on the specifics. Such an intricate process can take hours. "Kongki gave me a drawing of what he wanted, it was only a scale drawing. It still did not tell me much, and in the end, we went back and forth for a total of six hours filling in the blanks," Drier stated. This time does not include the actual building time. Drier says, "It's very challenging having to make new fixtures that allow scientists to do what they want to do." Like a fairy godmother, Drier brings UW's research drawings to life.

> **"Having to work with glass means working every day with a new challenge and new design... it never gets tiring to me."**
> **-Tracy Drier**

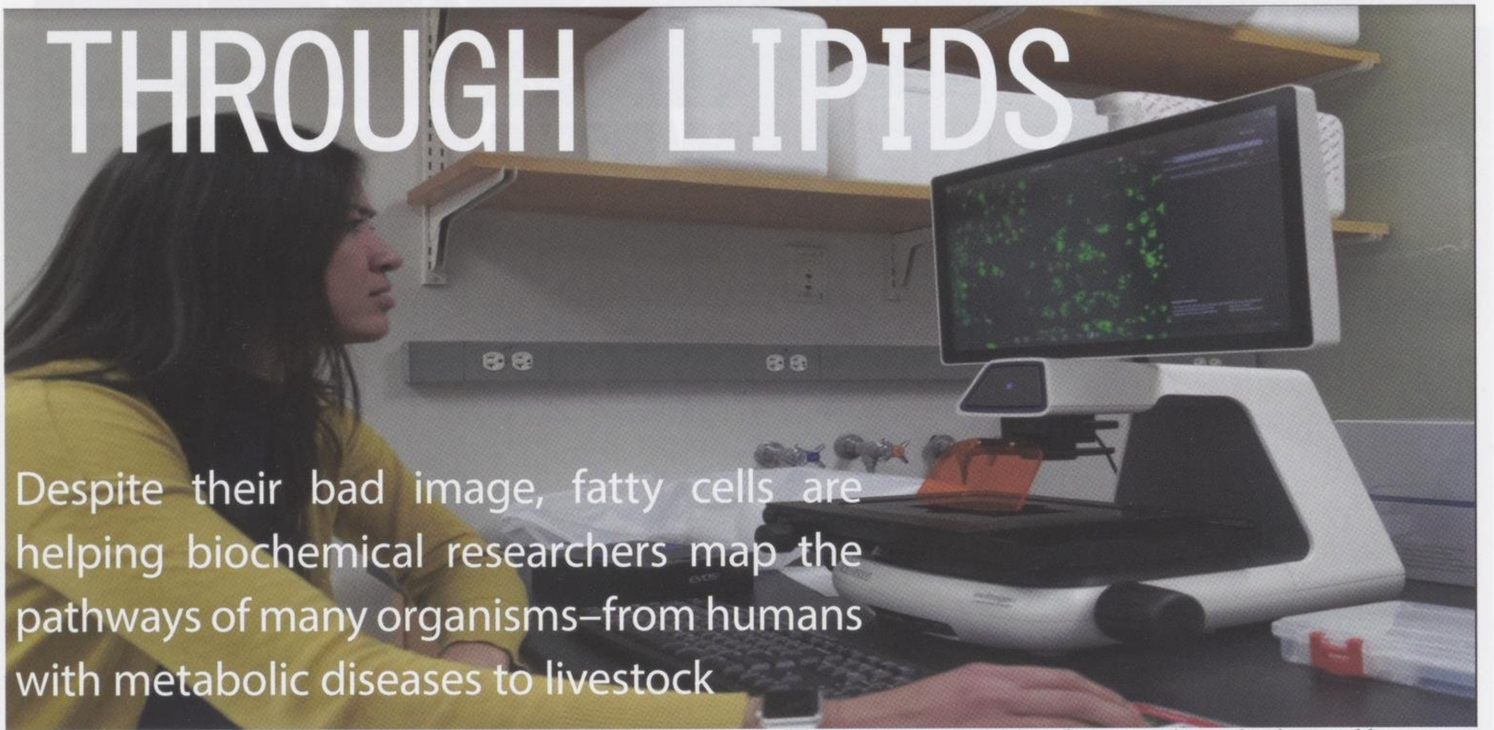
Drier started glassblowing due to his love for artistry and hands-on fabrication. We often forget the necessity of attention to detail, which thanks to Drier's motivation and dedication, is not a problem. Drier says, "Having to work with glass means working everyday with a new challenge and new design ... it never gets tiring to me."

The skill of repairing glassware and being able to mold it to certain specifications is rare. Scientists need new devices that have not been created and Drier's job is to bring experiments to life. Not only does Drier help researchers, but he also teaches a glass-blowing class for Chemistry graduate students. Drier says, "This job lets me interact with scientists…to be able to talk about the science behind my work is really exciting to me." He finds this job particularly rewarding since he can pursue his passion and learn new scientific discoveries.

Glassblowing is an underappreciated skill, which is why Drier is making many initiatives to jumpstart interests in the field. Drier says, "There is a need for glassblowers," because of their ability to create new fixtures. Evidently, science and art do not have to be mutually exclusive and Drier's glassblowing is a shining example.

Written by: Camey Zussman
Photography by: Jacobo Kirsch
Design by: Laura Rodricks

ORGAN COMMUNICATION THROUGH LIPIDS



Despite their bad image, fatty cells are helping biochemical researchers map the pathways of many organisms–from humans with metabolic diseases to livestock

Fat has a negative reputation of being the junk of the body and something we should aim to rid ourselves of. We've heard it all–cardiovascular disease, diabetes, high blood pressure–all associated with excess fat and obesity. While it is true that excess adipose cells can cause various health issues, adipose tissue is a crucial endocrine organ that informs the body of available energy stores. Moreover, lipid-fat molecules that compose parts of cells and circulate through our bloodstream play a crucial role in every organism's metabolic process. Lipids are responsible for duties ranging from storing excess energy to maintain body temperature.

Sustaining a body temperature that is favorable for biochemical reactions is paramount for survival. When an organism experiences extreme cold, there is a sudden increase in the demand for energy to produce the heat to maintain an optimal temperature. To sufficiently supply this increasing energy demand, our body utilizes types of fat cells called brown adipocytes. Brown adipocytes are tasked to increase both glucose and lipid uptake, converting them to energy. Activated brown fat is able to clear excess lipids and glucose from the bloodstream, making this tissue an attractive therapeutic target to treat obesity, diabetes, and many other metabolic syndromes.

Judith Simcox, an assistant professor in the biochemistry department at UW-Madison, is attempting to understand the sources of lipids circulating in our blood that fuel brown fat thermogenesis and uncover the cross-tissue communication pathways that regulate the production of these lipids. Specifically, Simcox is focusing her research on answering two major questions: how are liver-produced lipids taken up and metabolized in brown adipocytes, and how is hepatic lipid processing regulated in cold exposure?

> **"Brown fat cells can be utilized to treat obesity as it can increase both glucose and lipid uptakes of the body"**
> **– Judith Simcox**

In her research, Simcox exposed mice to an extremely cold environment and tracked the level of acylcarnitines, a type of lipid that is produced in the liver, particularly during periods without food. A sudden drop of temperature will trigger the release of stored lipids from fat cells which will be directed into the liver to be further processed. Due to this, Simcox chose to focus on the liver as the communicating organ for the adipose cells.

According to Simcox, there are two central goals in the medical field in relation to lipids: characterizing the many lipid species circulating in the blood to use them as diagnostic markers of disease and understanding how to clear excess lipids from the body in diseases such as cardiovascular disease and fatty liver disease. Simcox's research attempts to answer these questions by identifying circulating lipids in cold exposure and by activating brown adipose cells to increase the clearance of excess lipids.

In addition to its application in the medical field, this method also has potential in agriculture, particularly on livestock such as pigs. Simcox added that by observing the stress that temperature puts on pigs, we have the potential to find the optimal temperature for their metabolism. Because they do not have natural brown adipose tissues, pigs, especially piglets, are sensitive to cold temperatures and hypothermia, which is a major agricultural problem. To combat this issue, a "biomarker" of temperature is needed to know the optimal range of temperature for the biochemical reactions within the pigs. In order to do that, Simcox states that the understanding of all metabolic pathways is crucial, as the pathways can provide agricultural scientists much detail on the sustainment of the body temperature.

Simcox hopes that in the future she will be able to identify biochemical pathways that regulate metabolism that is altered in metabolic diseases such as fatty liver disease and by tracking lipid species to their final destinations. From the medical field to the farm field, mapping lipid pathways has enormous potential that will help eradicate the negative stigma of fat.

Written by: Alfred Sunaryo
Photography by: Evan Birschbach
Design by: Laura Rodricks

Neural Connections Across Campus

UW-Madison professor Aviad Hai is developing tiny electronic sensors to study brain activity using MRI

A magnetic resonance imaging (MRI) scanner can be used to take detailed anatomical snapshots of the brain non-invasively—without harming the brain. It can even detect changes in the flow of blood related to brain activation using what is commonly referred to as functional MRI (fMRI). Neuroscientists and neurologists have been using fMRI extensively to study the brain and to diagnose and monitor neurological disorders. But a longstanding difficulty with fMRI is the ambiguity of the measurements it provides and the fact that blood flow in the brain is only loosely related to actual electrical brain activity. The signals deep in our brain are electrical pulses generated by billions of brain cells, and at this time we can only read them with very invasive surgically implanted probes. Assistant Professor Aviad Hai and his team at the biomedical engineering department at UW-Madison are trying to solve this problem by developing new types of microelectronic sensors which will allow a typical fMRI measurement to become specific to electrical signals in the brain. These technologies can revolutionize the way we read brain activity.

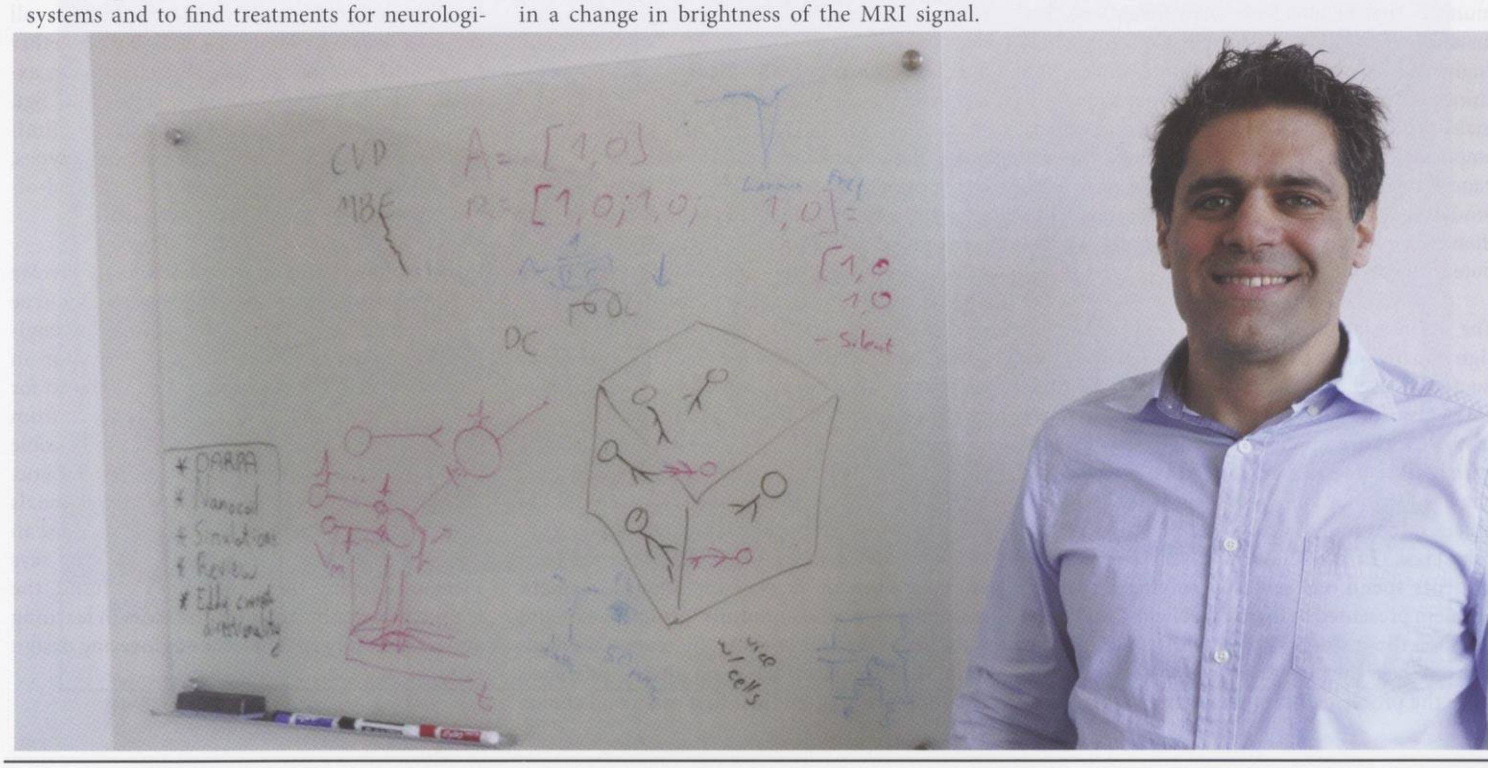
Hai joined UW-Madison this past January after finishing his postdoctoral work at the Massachusetts Institute of Technology (MIT) and is excited about the "surge of research in neural engineering" that is occurring on campus. Neural engineering is an emerging field within the biomedical studies and uses engineering technologies to study the function of neural systems and to find treatments for neurological disorders. Research labs in this field at UW-Madison focus on minimally invasive methods to read from the brain and the development of implantable devices and materials for neuroprosthetics. Hai has also found that UW-Madison offers a more personal connection, "the people here are unique, there really is a spirit of Madison," says Hai, adding that, "there is a deep sense of community between different departments when it comes to research." Hai believes that this community-based environment at UW-Madison will provide outstanding support for his research.

"I feel that it's a must, to understand the brain, to understand how it works, and we can't do that without reading brain activity directly from the entire brain in parallel." – Aviad Hai

Hai's lab concentrates on developing minimally invasive tools that will allow access to the nervous system for studying brain function. Hai has been developing micro- and nanoelectronic circuits that act similarly to a standard radiofrequency tuned antenna. This type of device is connected to a micro-transistor that senses electrical pulses in the brain. These pulses change the device's resonance and result in a change in brightness of the MRI signal. This allows for brain activity to be monitored directly and is now opening the door to a better understanding of how the brain works, "I feel that it's a must, to understand the brain, to understand how it works, and we can't do that without reading brain activity directly from the entire brain in parallel" says Hai.

The human brain is the command center of the central nervous system. It receives information from all parts of the body and uses this information to make decisions and react, but exactly how it all works is still a great unknown. However, what we do know is: neurological discoveries won't be made by just one person, but by a community of neuroscientists, engineers, and doctors working together. There are no physical borders between neuroscience and neuroengineering, only mental ones; similarly, there is no point where a scientist's work ends and an engineer's begins. Hai believes that we can do more to bridge the gap between medicine, science, and engineering to solve the hardest questions. By uniting neuroscience and engineering, Hai is advancing one step closer to seeing and understanding the whole brain.

Written by: Makenna Hall
Photography by: Taha Sawar
Design by: Lujain Al Jumah



Sergeant Stubbs: A Feline Engineering Feat

A young cat, Sergeant Stubbs, lost both his hind legs last year in a train accident. Find out how first-year engineering students helped him lead a better life...

In recent years, rapid engineering innovations have created a symbiotic relationship between engineers and local and international communities that benefit from their inventions. For instance, innovations in the field of biomedical engineering are often geared towards helping machines efficiently interact with humans and animals. With the goal of making the lives of many amputees easier, prosthetics technology has advanced remarkably in the past two decades, with models that are more reliable, efficient, and lifelike than earlier versions – a feat driven largely by amputees' demands.

The flexible, fast-paced world of engineering design churns out rapid innovations not only at a doctorate level, but even in first-year undergraduate classes at UW-Madison. As advancements in this field are applicable to both human and animal amputees, Professor Kathryn Kalscheur has adopted a unique approach to teaching engineering through InterEGR 170: Design Practicum class. In this class, first-year engineering students spend one semester solving a real-life problem presented to them by a client. "My role is to guide these students through the design process and help them get the resources they need to solve the problem. The students really take ownership of the project, which provides them with the best learning," says Kalscheur. This semester, students took responsibility of quite a unique project on behalf of the Community Cat Rescue Team – fabricating prosthesis for Sergeant Stubbs, a young cat who lost both his hind legs last year in a train accident.

From brainstorming prototypes to fabricating the prosthetics at the MakerSpace on campus, students gained valuable experience of the engineering design process. "The goal of all of our projects is that the clients benefit from receiving a solution to their problem through the innovation and hard work of our engineering students, while the students benefit by getting experience working with a team to implement the design process with a real client," says Kalscheur.

On the first day of class, students are presented with a variety of projects shortlisted by the instructor, most of which are for "people who have a unique need because of a disability, while some are custom-made devices for schools, farmers, researchers, and community groups," explains Kalscheur. Before working in teams, students rank their projects based on their preference, and most are allotted their first or second choice. Most of the roles require good leadership skills. This means students get the best of both worlds – they learn to work independently, while gaining the experience of teamwork. "In our team, … all of us [choose] our own roles and work together towards an end result," says Pierson Fisher, external communications manager of the Sgt. Stubbs project. "Students also present preliminary designs to the client, fabricate prototypes, write the final report, and present at the end-of-semester poster session," says Kalscheur.

Projects undertaken in this class mostly involve the students, connecting them with the true meaning and experience of a career in engineering. However, designing prosthetics for an animal is considerably harder than doing so for humans due to limited input and feedback from animals. Nevertheless, it's not entirely impossible to judge the animal's response to the prosthetic. "What we have done is consulted professionals and tried to understand what has been done in the past, but that information is limited," says Pierson. Keeping these challenges in mind, the team made significant advancements in learning and successfully applying the engineering design process.

"The first step in the process is defining the need," says Kalscheur. "We began with a client consultation, specifically aiming to understand how Sgt. Stubbs is disabled. We found that his legs were different lengths, meaning different prosthetics served different purposes," says Pierson, adding, "the next step was to size the prosthetics correctly, to make sure it will fit and stay on." Most of the design process also involves generating multiple solutions by individual and group brainstorming. "[Design] is an iterative process where the generation of solutions and testing often requires going back to the research stage and further brainstorming of solutions," states Kalscheur.

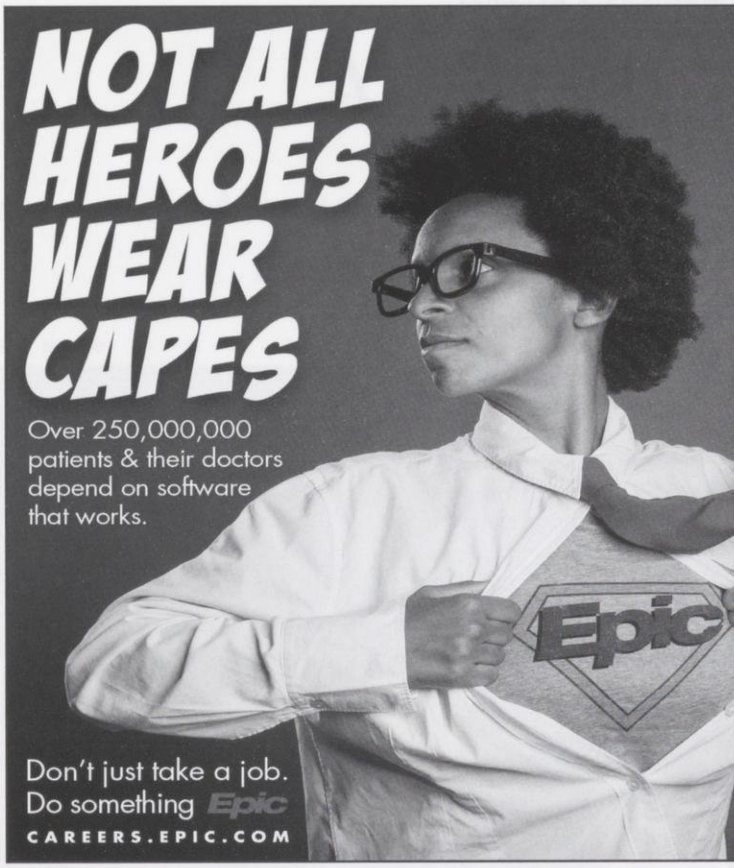
As the world of engineering design is constantly evolving, it is important to consider creating new and improved designs for prosthetics and other machines worldwide. As one of the goals of prosthetics is to be durable and easily replaceable, "... further refinements [on Sgt. Stubbs' prosthetics] will be made as necessary and rapidly prototyped at the MakerSpace on campus," claims Kalscheur. Compared to a standard first-year course, working on projects that directly impact the real-world is very rewarding and "a highlight of the [first-year] coursework," according to Kalscheur. Aside from being a great opportunity for building professional skills and networking with the College of Engineering staff and students, "[these projects] show the community that college students can change lives," says Pierson.

A team of first-year college students working towards brainstorming, designing, and fabricating prosthetics for a disabled cat only goes to reinforce the importance of engineering in the real-world. "The Accreditation Board for Engineering and Technology (ABET) defines engineering as a profession in which a knowledge of the mathematical and natural sciences, gained by study, experience, and practice, is applied with judgment to develop ways to utilize, economically, the materials and forces of nature for the benefit of [society]," says Professor Kalscheur. However, an engineer's work is more than just repetitively producing technical solutions. The world is changing, now more than ever, and engineers lead this fast-paced change with each refinement, each upgrade, and each invention. The goal of engineers worldwide is to make the world more efficient and productive while also making it a great place to live. Every device an engineer lays their hands on, creates, or recreates not only affects the present, but also the future. Engineers don't just sit back and watch. They make things happen.

Written by: Nandan Venkatesan

Photography by: Taha Sawar

Design by: Lujain Al Jumah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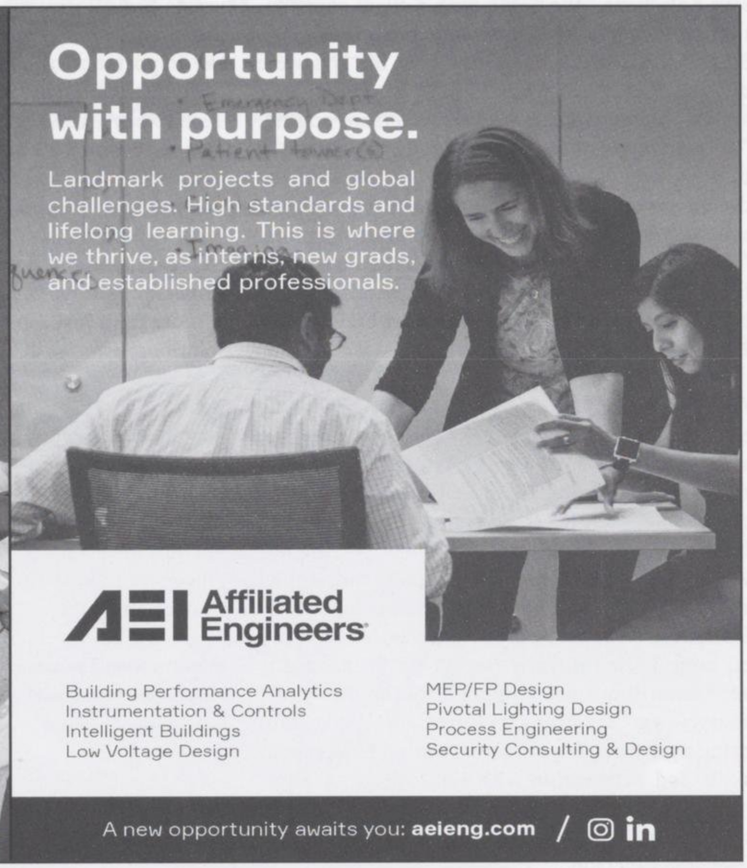
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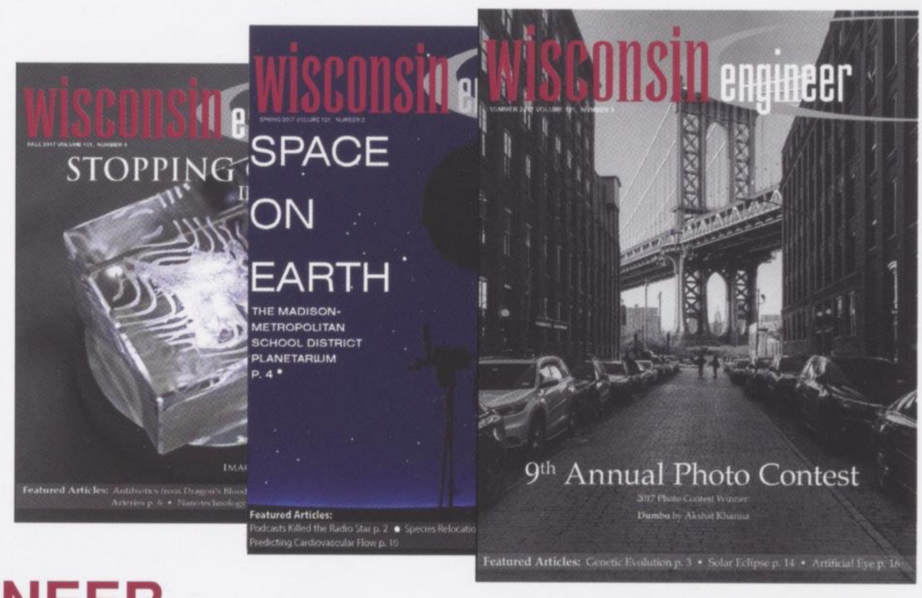

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