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SUMMER 2019, VOLUME 123, NUMBER 3

11th Annual Photo Contest

2019 Photo Contest Winner: "Future World Exhibit" by Megan Parker

THE ENGINEERS' CROSSWORD PUZZLE

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wisconsin engineer

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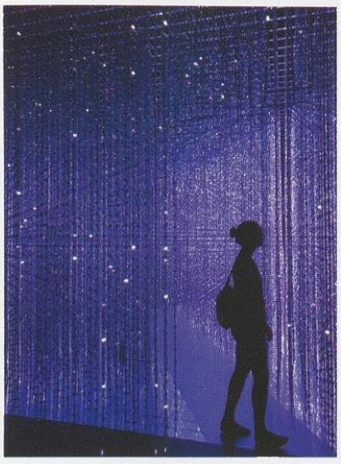
General



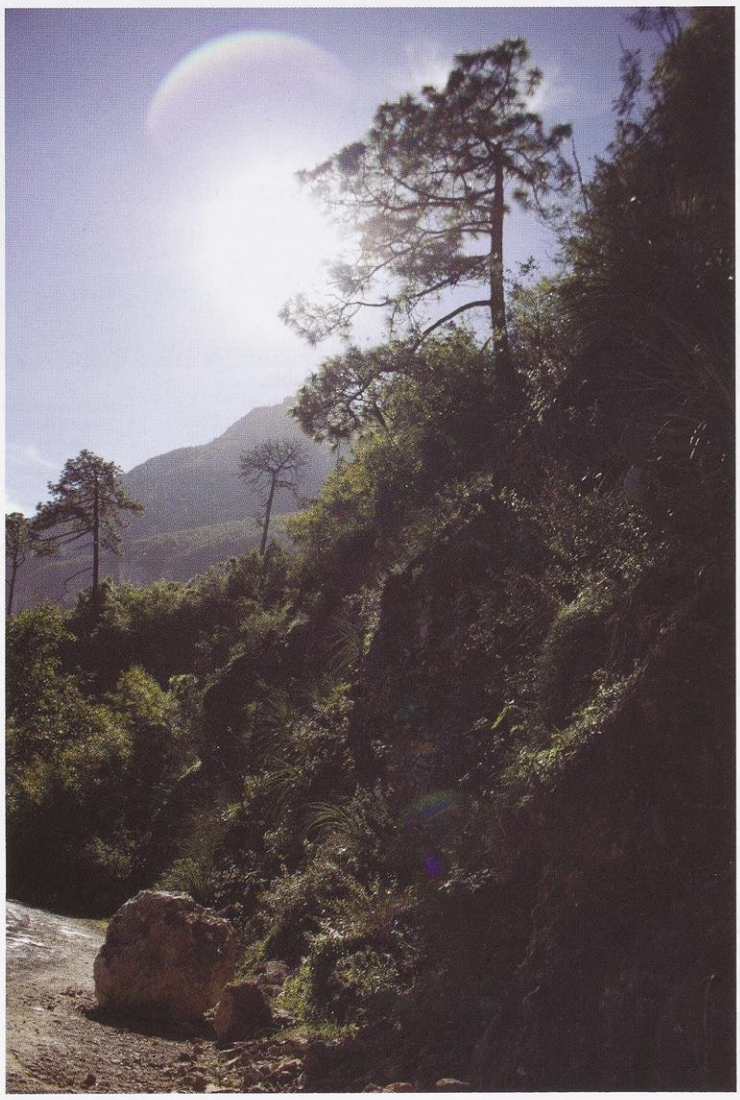
Cover photo:
11th Annual Photo Contest Winner
"Future World Exhibit"
Megan Parker

Burning in the New Year

Dr. Monica Turner's ecological research helps better understand the fires that have been consuming the West Coast.

Among the many images of last year's news cycle, none were more striking than massive fire defense planes bursting through the sky and dropping a wall of bright red fire-retardant on dry California landscapes. These defense tactics were in response to the deadliest and most destructive season of wildfires. These wildfires burned more area and injured more people than any year prior. Although news stations did an excellent job fanning the flames of hysteria, they often missed the nuanced scientific data behind the wildfires, which is crucial to understanding and ultimately preventing such destruction in the future.

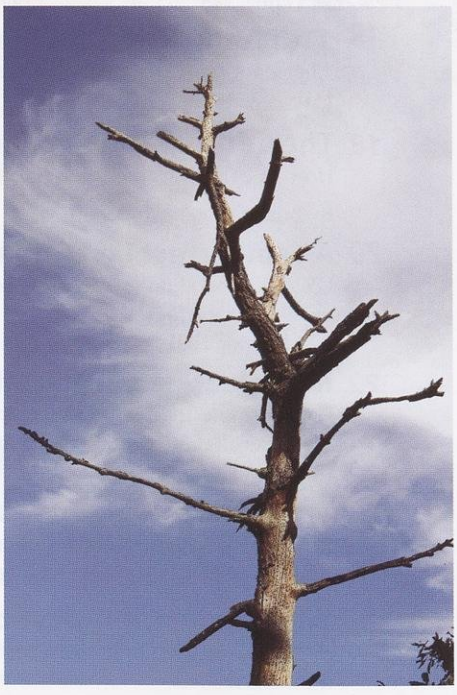
Dr. Monica Turner is well acquainted with the science behind fires as a landscape ecologist in the department of integrative biology at UW-Madison. Dr. Turner's nascent interest in fire and its effect on landscapes grew during the 1988 fire season in Yellowstone National Park. The 1988 season "...ushered in a new era of wildfires to the western United States," Turner explained. The year produced unusually high temperatures and little rainfall, which continues to be seen to this day.



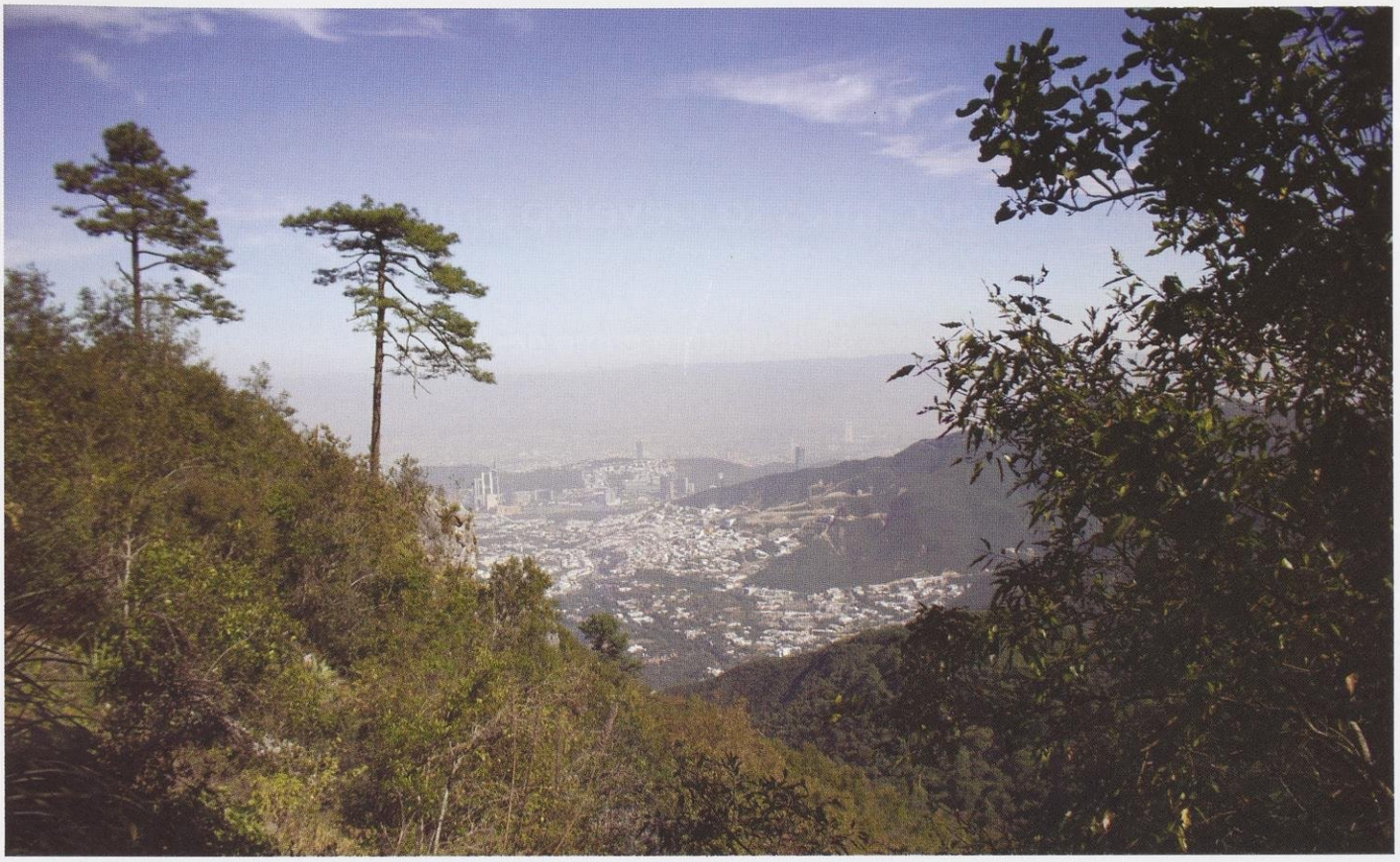
"A whole new era of wildfire [is occurring] in the western United States."
- Dr. Monica Turner

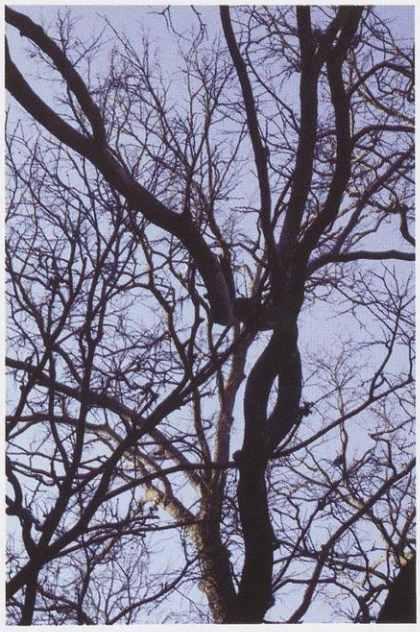
"People thought Yellowstone was destroyed," says Turner. It is common for forests in the western United States to experience wildfires and return to their original state, or their "climax community." What is concerning, however, is that Western high elevation forests like Yellowstone can only sustain recovery if wildfire happens infrequently. Unfortunately, hot, dry conditions are becoming the norm as climate change becomes more severe.

As climate change continues to present challenges, Dr. Turner hopes to meet it earnestly with data and research in hand. By applying computer simulations and models to fire data, she can predict how fires will act and how forests will recover in the future. Dr. Turner began using percolation theory when she noticed the mosaic of burn marks in Yellowstone, as opposed to consistent burn. Percolation theory describes the flow of substances from one point to another and reveals insights to patterns and movements, as in the case of wildfires.



Currently, Dr. Turner's lab focuses more on secondary succession, how species develop after fires, and how it is changing with an increase in frequency of fires. Dr. Turner concludes that useful data is at the heart of her research, just as engineering is at the cross section and data and biology. Engineers help people like Dr. Turner collect data by making the devices such as drones and other tests simple and efficient. The goal of this data collection is to aid in the recovery of habitats in California and prevent the destructiveness of future fires.





The effects of wildfires can be seen in Chipinque Park in San Pedro, Mexico.

Not all fires are destructive, however. Dr. Turner insists, "Some prairies of Wisconsin were maintained by fires." Something often overlooked in most stories about wildfire is that they are crucial to maintaining habitats. Before European settlement, oak savannas, defined by a low density of oak trees which allows grasses and other shrubs to grow, dominated most of southern Wisconsin. Low intensity fires maintained these now-endangered landscapes because mature oak trees with thick bark were able to withstand the fires. Quick growing vegetation, like grasses, succeeded after fire episodes. Some tree species, like the lodgepole pine, are even adapted to prosper when fires occur. The lodgepole has pinecones which are tightly packed and only open when heated to the high temperatures of a forest fire. Surprisingly, this is a smart strategy, because after a forest fire there is little competition for growth.

While wildfires have the power to destroy, they also make way for other species and habitats to prosper. Although they leave trails of destruction such as in California, Dr. Monica Turner hopes to better understand wildfires through data analysis. With enough research and action in the face of the growing consequences of climate change, scientists will be better able to mitigate and prevent future intense fire seasons.

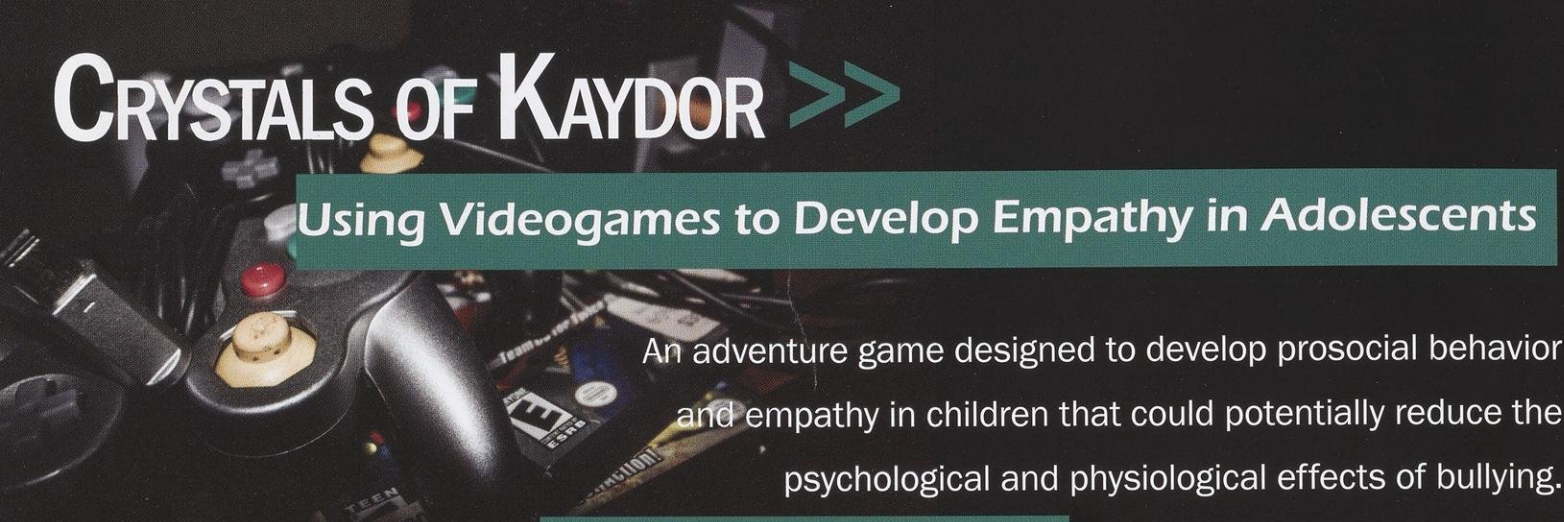
Written by: Ben Hayes

Photography by: Jacobo Kirsch

Design by: Isabella Wegner

Crystals of Kaydor >>

Using Videogames to Develop Empathy in Adolescents



An adventure game designed to develop prosocial behavior and empathy in children that could potentially reduce the psychological and physiological effects of bullying.

During adolescence, many individuals will encounter their first experience with psychiatric illnesses, such as anxiety or depression. Many of these mental illnesses are brought on by the difficulties of social adjustment. This comes as no surprise as according to the Waisman Laboratory for Brain Imaging and Behavior at UW-Madison, 36% of adolescents are victims of bullying. These issues can cause serious long-term health consequences such as suicidal idealization, suicide attempts, and systemic inflammation.

Research has indicated that one of the most active defense mechanisms against bullying is empathy. According to the Department of Curriculum and Instruction at the University of Wisconsin-Madison, adolescents with stronger empathetic skills are less likely to internalize bullying and are less likely to be targets of bullying. Not only does this allow adolescents to develop positive and supportive relationships, but it can also reduce the long-term effects of physical and psychological stress.

The promising relationship between strong empathetic skills in children and a healthier adolescence has researchers engineering tools that develop emotional intelligence. Specifically, the Center for Healthy Minds (CHM) and Gear Learning (formerly Games+Learning+Society) at UW-Madison has taken on the challenge to create a platform to mature empathetic skills in adolescents. The team is devoted to developing tools for the mental well-being of people and has collaborated to develop Crystals of Kaydor (referred to as Crystals), an adventure game for the iPad designed to develop prosocial behavior and empathy in children.

Tammi Kral, a doctoral candidate in psychology at UW-Madison and lead researcher involved in the study states, "This work is particularly exciting given the massive scale at which pro-social videogames could affect change– some sources estimate between 1.5-2 billion people play videogames worldwide." The team uses videogames as their platform not only because of the appeal of exposure but also because adolescents are drawn to the videogames and enjoy engaging in this medium, which can facilitate training. External research by Dr. Tobias Greitemeyer and Dr. Silvia Osswald has also demonstrated that playing videogames with a pro-social context improves social behavior.

Crystals is a game that is designed to develop empathy in adolescents through perspective taking, a technique in which one approaches an emotional situation with a third-person viewpoint. In this study, the team examined the brain response of adolescents prior to videogame training, and determined that adolescents are most empathically accurate, meaning to correctly identify another's emotions, when they use perspective taking rather than to directly relate to the situation through sharing in the other person's emotional experience. Additional research has determined that this is because adolescents struggle with emotional regulation, or the ability to monitor and control one's behavior. As a consequence, adolescents have a negative brain-behavior relationship when they use experience sharing to be empathic.

In the game, the user plays as a robot who is stranded on a distant planet. To survive, the player must form a relationship with the aliens of the planet by learning to interpret their six basic emotions (anger, fear, happiness, disgust, and sadness) through humanlike facial expressions at varying intensities. Once the player successfully identifies the six emotions, they can respond with the six similar facial expressions and will receive positive reinforcement when they respond using the correct emotional expression. The game continues to develop pro-social behavior in the player as they go on quests with the aliens to solve problems and learn to respond to different social situations. The stunningly colorful graphics of Crystals and the narrative portion of the game makes this a compelling and engaging tool to develop prosocial behavior in adolescents. Kral states, "Prosocial videogames, such as empathy training, have the potential to improve the wellbeing of individuals, as well as to contribute to a kinder, more compassionate world."

To gauge the effects of the game, the team measured whether the game would improve empathic accuracy, stimulate empathy-related brain activation, and further develop the brain network associated with empathic processing in adolescents. The team tracked game-play data and recorded any changes in the brain associated with higher empathic accuracy, perspective taking and emotional regulation. Specifically, they looked to see if there was an increase in connectivity and structural changes of these regions and activation through resting state functional magnetic resonance imaging (rs-fMRI) scans.

While there were no measurable behavioral changes, the training portion of the game where the player learns to identify the underlying emotions of the aliens increased empathy-related brain activation. In addition, rs-fMRI scans reported an increased activation of the perspective-taking regions of the brain. Consequently, the team hypothesized that playing Crystals teaches adolescents to recruit the parts of their brain associated with perspective-taking in order to be empathically accurate. Furthermore, the group predicted that developing regions of the brain associated with emotional regulation would improve the empathic accuracy of adolescents. Surely enough, participants that had improved empathic accuracy had strengthened areas of the brain associated with emotional control. The team interprets the development of this connectivity as evidence of improving emotional regulation in adolescents.

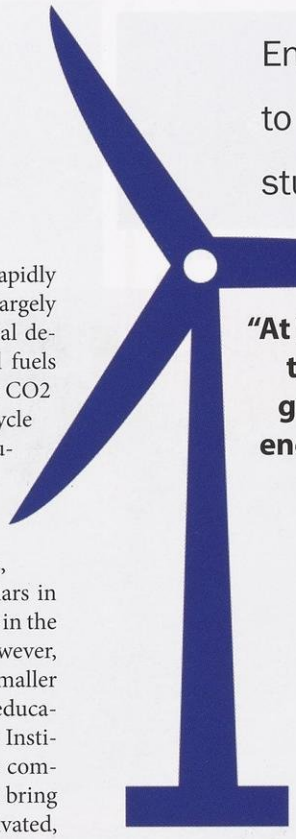
The results of this study from measurable improvements in empathy-related brain activation and brain connectivity are likely to have a positive impact on adolescents. The team anticipates exploring more long-term studies to determine the role Crystals could have in developing prosocial behavior in participants. If the game has a positive impact, it would be valuable in its ability to develop important psychological skills in adolescents that will allow for the negation of the effects of bullying.

Looking forward, the team hopes to develop additional features for the game, such as more emotional expressions and more challenges involving empathic accuracy. This game has proven to be incredibly promising and valuable for strengthening adolescents' empathy-related brain networks. Kral reiterates, "We are only beginning to explore this space, which provides a unique medium to blend the creative arts, learning sciences, and neuroscience to develop effective, engaging training." Videogames are a promising platform to not only facilitate positive adolescence, but to develop a future society of compassionate individuals.

Written by: Sofia Noejovich
Photography by: Hamoud Alshammari
Design by: Isabella Wegner

WiscWind
Building a Sustainable Future

Engineering and business students collaborate to create the perfect wind turbine through the student organization, WiscWind.



Global carbon emissions have been rapidly increasing within the past decade, largely due to the recent boom in industrial development. The energy-driven use of fossil fuels such as gasoline has led to a rapid increase in CO_2 emissions, disrupting the global carbon cycle and contributing to climate change. One solution to counter the effects of this man-made destruction is the use of nature's renewable resources to fuel our continuously developing world. Large multinational companies, such as Tesla, have invested billions of dollars in solar power and energy storage technologies in the hopes of inducing a worldwide change. However, great change is often the result of multiple smaller changes. Scott Williams, a research and educational coordinator at the Wisconsin Energy Institute, is encouraging today's youth to create community-wide changes. To do this, he helped bring together WiscWind: a group of highly motivated, sustainability-oriented undergraduate students.

"At WiscWind, we're training the next generation of the energy workforce." - Scott Williams

WiscWind aims to develop efficiently designed wind turbines and place them at various sites that allow for maximum power output and minimum discomfort to the public. "In many parts of the Midwest, wind turbines are the most cost-effective and renewable way to produce energy. For example, in states like Iowa and Oklahoma, 30% of electricity is derived from wind turbines," Williams says, adding, "...creating an interest in wind energy through a student organization ...allows for a more interactive, closely-knit community." WiscWind accepts students of all majors, and is comprised of business, economics, and engineering majors working towards the same goal of sustainable energy. "Each one is doing something that actually intrigues and excites them. Our students come in knowing that they're doing something that actively contributes to society," states Williams.

Representing UW-Madison in the Collegiate Wind Competition hosted by the U.S. Department of Energy, the organization is divided into two teams: the siting team that tackles the siting challenge and the design team that tackles the design challenge. The siting team focuses more on the business side of things; they work on financial matters, choose the location of the turbines to create a 100-megawatt wind farm, research environmental impacts of the project, and so on. The design challenge, on the other hand, is more technical and is executed by students in the College of Engineering working to design more efficient blades, electrical system, generators, and controls. WiscWind focuses on one goal– creating the most efficient wind turbine by seamlessly integrating and developing the teams' knowledge of wind turbines. But by splitting the project into two components, the team creates a more systematic, streamlined workflow, thereby producing a refined end result.

Although it may seem that there are only so many ways to design a wind turbine, there are many small changes that can improve the overall design of the turbine by making it more energy efficient and helping reduce pollution. In the final stages of the Collegiate Wind Competition, groups are required to submit a technical report including the design of the wind turbine and a justification for each design element. In order to make the WiscWind experience similar to the professional design process, both teams interact with the judges and discuss various factors that will help the judges evaluate the team's design and select a winner.

"The competition has something new every year so there's always the aura of a challenge, there's always something to improve upon every year," Williams adds, "...at WiscWind, we're training the next generation of the energy workforce." In addition to enhancing one's interpersonal skills, many gain leadership experience as part of the WiscWind team. Most seniors lead various technical divisions of the WiscWind design team as part of their senior design projects. All designs, ranging from preliminary to the final version, are fabricated at UW-Madison's facilities, such as TEAM Lab and MakerSpace and are tested in the wind tunnel at Engineering Hall. As competitors in the Collegiate Wind Competition since 2015, WiscWind has something to offer to all students. "The organization is open to students of all years. It's up to you to figure out where you'd fit in and where your skills would be best applied," Williams says.

In an effort to inspire future generations of the energy workforce, WiscWind also participates in the Engineering EXPO, a two-day annual event run entirely by students which took place April 5th and 6th for 2019, and the KidWind Challenge that inspires middle school and high school students to develop their own prototype of a wind turbine. Organizations like WiscWind are vital in promoting our global energy market's need to switch to renewable resources and create a real change in the community. Small steps like these can lead to big changes in our planet. Given that our demand for energy will only increase, there is no better way to make a change than to actively improve your local community and global climate.

Written by: Nandan Venkatesan

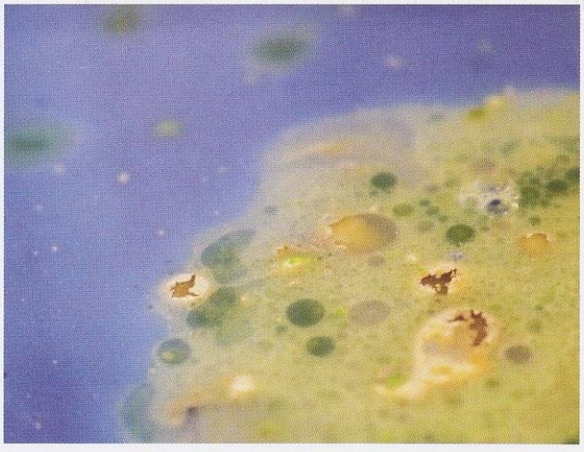
Design by: Laura Rodricks

Wisconsin's Lakes: The Mercury Conundrum

Carl Watras and a team of Wisconsin scientists have discovered an interesting correlation between water levels and mercury contamination in Wisconsin's Lakes.

While the battle against pollution and fossil fuels has captivated the world in recent years, Wisconsin has been at the forefront of this war for over 50 years. From Wisconsin Senator Gaylord Nelson founding the idea of Earth Day in 1970 to the passing of the nation's first acid rain legislation in 1986, Wisconsin has been a model for ecological advocacy. Thus, it is no surprise that another environmental revelation has recently originated from the Badger state. A team of scientists from UW-Madison and the Wisconsin Department of Natural Resources has unearthed a surprising correlation between mercury contamination and water levels in Wisconsin's lakes.

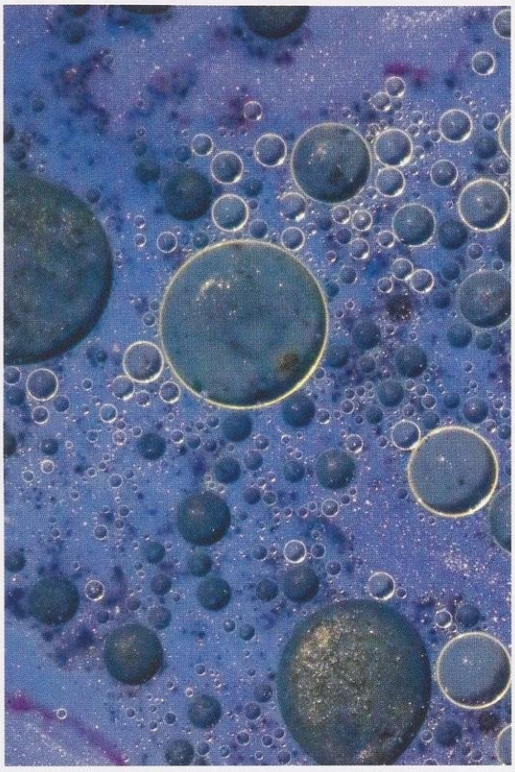
The findings come out of UW-Madison's Trout Lake Station, an environmental and limnological research center located in Vilas County. Trout Lake Station's proximity to over 12,000 lakes makes it an asset to research fellows such as Carl Watras, who has spent over 30 years at the location. A particularly remarkable achievement of his was helping publish a scientific paper in 2014 that quelled widespread fear about the condition of Wisconsin's lakes.



An interpretation of mercury's effect on water.

"In the past 70 years, water levels had never been lower than what they were in 2014," recalls Watras. "People were panicking." Watras's team was able to prove that there are regional water level swings that typically last 13 years from high peak to high peak. For example, 2018 was considered a high-water-level peak, meaning that 2005 should have been the last high-water-level peak. However, the actual last high-water-level peak occurred in 1998. This is what sent many people into a panic in 2014: the low water level peak was uncharacteristically low and was lasting an exceptionally long time. Why did this last water level swing last so long? As Watras explains, "The differences between the amounts of evaporation and precipitation can change, and this drives the water level oscillations. The oscillation itself is a climatic signal. It's like

"In the past 70 years, water levels have never been lower than what they were in 2014."
- Carl Watras



"Water level oscillations are driven by the differences between the amounts of evaporation and precipitation. The oscillation itself is a climatic signal. It's like a heartbeat."
- Carl Watras

One seagull at the shores of Lake Mendota.

a heartbeat." It was from learning about these water level oscillations that Watras and another team of scientists were able to find the correlation between water levels and mercury contamination.

Since 1982, the Department of Natural Resources has been tracking the length, weight, and mercury concentrations of walleye so that this data may be used for research purposes. If mercury concentration is plotted against regional water levels, as Watras did, there is a strong correlation. After, Watras and his team had to determine the meaning of this relationship. What they found out was truly astonishing.

As water levels recede over time and more land is exposed to the atmosphere, mercury that is present in a lake is deposited on its shores. The newly exposed land eventually becomes home to grasses, shrubs, and trees, which absorb this mercury and store it. When the water returns to its original levels, these plants drown and are decomposed by bacteria that eventually use up all the oxygen in the flooded zone. Those conditions set the stage for another group of very primitive bacteria that thrive in oxygen-free environments. These bacteria take up mercury and convert it to an extremely toxic waste product: methyl mercury. This toxin eventually works its way through the food web and concentrates at the top of the food chain by a process known as biomagnification. This means that the methyl mercury builds up in predators such as walleye and largemouth bass, making these fish ideal for tracking the mercury contamination in lakes.

Now that a correlation has been established between water levels and mercury contamination using walleye data, Watras and his team are beginning to investigate if other animals exhibit a similar trend. "We are looking to see if we get the same pattern with loons as you do with walleye," explains Watras. Loons have basically the same diet as large walleye, so it would make sense to see the same relationship to water levels. That's the current hypothesis. He hopes to find out more about mercury contamination and its effects on lakes by using data from multiple animals. With each discovery that Watras and his team make, they continue to uphold Wisconsin's rich tradition of environmental advocacy.

Written by: Johnathon Brehm
Photography by: Jacobo Kirsch
Design by: Patricia Stan

How Hearts Break Differently

UW-Madison professor Kristyn Masters is researching how male and female hearts break differently; that is, the distinct progression of calcific aortic valve disease between sexes.

What's worse than heartbreak? Perhaps not knowing why, on a cellular level, they may break. When it comes to females with calcific aortic valve disease (CAVD) that may be the case. Although we have some knowledge (albeit, limited) about CAVD, Kristyn Masters, Vilas Distinguished Achievement professor and Vice Chair of the biomedical engineering department at UW-Madison, is discovering that what we do know about the disease may only apply to males.

Seven years ago, Masters' lab discovered that male heart valve cells underwent significantly more calcium buildup than female cells. A 2016 study verified this finding, showing that the female cells were instead undergoing fibrosis (experiencing a buildup of collagen fibers) to reach the same severity of clinical disease. Some researchers have begun to adopt the name "fibrocalcific aortic value disease" rather than CAVD to account for this discrepancy.

"We tend to think of [sex] as an organism-level variable," Masters says. "But on a cellular scale, it matters." Masters recently received a $1.5 million grant from the National Institutes of Health (NIH) to further her research on the differences between sexes in the progression of CAVD. Her lab has discovered distinct pathologies in tissue engineered models of the disease based on the sex of the original heart valve cell. "I don't know any more if this is even the same disease," she says. With this NIH grant, Masters plans to continue studying the differences between sexes in the later stages of the disease, as it seems to begin with a similar pathogenesis in male and female cells. Her lab will be treating the cells with different risk factors for CAVD, including high cholesterol, metabolic syndrome, and smoking to determine the response of each sex.

As far as tracking sex as a biological variable, Masters believes it is the next step for all cellular-level research. "This matters," Masters says. "Even if you're not looking at sex differences when you're doing your cultures, you should at least know what [sex] cells you're dealing with." When first presenting on this idea, Masters explains she received some resistance. Her discovery, like many new discoveries in the evolution of science, has implications questioning the validity of previous studies. Hers challenges the legitimacy of using mixed-sex cells, a common practice in cell culture science today. It also implies a "two-fold" work load for researchers, as all trials will need to be conducted on both male and female cells. In addition, it may be difficult for researchers to know with certainty the sex of their cells based on their supplier. "It's going to be hard for a lot of people," Masters admits.

Despite the initial hesitancy, steps are being taken to legitimize the importance of sex as a biological variable. The American Physiological Society has since begun to require all manuscripts submitted must report the sex of their cells. Similarly, NIH has recently implemented a mandate that all grants must discuss sex as a biological variable for vertebrate animals, including humans, but not for cells. "We're getting there," Masters says.

"We tend to think of [sex] as an organism-level variable, but on a cellular scale, it matters."
- Kristyn Masters

In the upcoming months, Masters and her lab will continue to investigate the differences in CAVD by sex with hopes to uncover the first treatment to slow the progression of the disease– a treatment that could be sex-specific. Armed with this knowledge, we will be better equipped to understand exactly how hearts break– both male and female.

Written by: Sydney Heimer

Design by: James Johnston

Design, Design, and More Design

Biomedical Engineering at UW-Madison

An overview of the unique structure of the Biomedical Engineering design curriculum, including an administrator's and a student's thoughts on what makes it so special.

For many disciplines of engineering at UW-Madison, senior design classes have a familiar format. Students complete a rigorous capstone project during their final semester, designed to draw on the full body of knowledge they have gained over their college career. However, for students in the biomedical engineering program, capstone design takes a vastly different form.

In the BME program, students begin taking design courses starting in their freshman year. Then during their sophomore year in BME 200 – Biomedical Engineering Design, they select projects that ultimately pair them with teams of juniors in the program. Each team then spends the semester working together on solving their own real-world problem in the field of medicine, such as designing a prosthetic for someone with a specialized medical condition. This mentorship reflects the program's theme of continuity, despite varying levels of experience. All BME students are in the same design class, and all team projects are drawn from the same pool. Each semester of a BME student's design track fittingly follows the same format: selection of teams and projects, drafting of potential solutions to a problem, selection of a final design, and development of that design culminating with a formal presentation and a poster exhibition at the semester's end. The second semester, BME 201 – Biomedical Engineering Fundamentals and Design, is the only one that takes a different shape. Rather than working on their own problem, each team of sophomores works at solving a common problem without the mentorship of junior students. This way, BME students all gain the same standardized set of technical skills and have the opportunity to explore various emphasis areas.

As juniors in BME 300 – Biomedical Engineering Design, students assume the role of mentor and use their experience from BME 201 to guide the selection of their project discipline. From there, they are off to the races. Students will typically work on the same project with the same team members for their last three semesters, certainly for their final two. Over the duration of the design track, their teams become more specialized and their projects more specific, as students gradually home in on the sort of career they want to pursue following graduation.

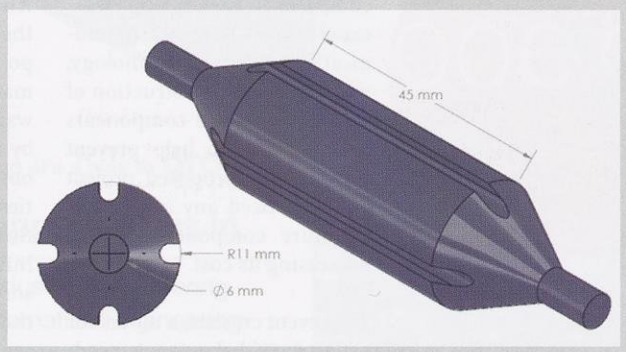
Dr. John Puccinelli, coordinator and instructor for the program, emphasized that the program's greatest strength is the way in which its structure aids students in pursuing their passions. "You can learn all the theory you want, but until you get into something that applies it, you don't necessarily see what it's good for… It helps them realize, 'I really like this aspect of the field, so I want to take more classes that are related to it'" says Puccinelli.

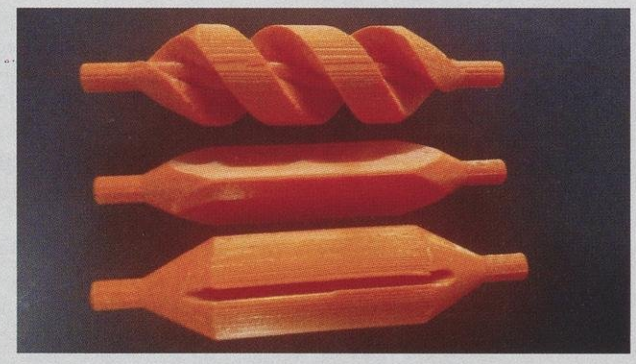
The program facilitates this construct through an incredible amount of faculty involvement. Each team of students is assigned a faculty advisor who has experience in a field related to their project. The teams and advisors meet for at least thirty minutes each week. This leads to a student-faculty ratio of four or five to one – unusual for any course at UW-Madison, let alone one that typically has more than 300 students. As a result, BME students build long-lasting connections with faculty across the program. "I don't get to know my students that well in any other class," says Puccinelli, "because I don't have much meaningful interaction with them beyond maybe office hours."

"Design isn't about just knowing one thing. It's about pulling information from a lot of different subjects into one whole project."
- James Jorgensen

According to James Jorgensen, alumnus of the program and current BME graduate student, this faculty involvement contributes to what he sees as the program's most valuable component: its multidisciplinary nature. "Everyone in the BME department is there to help you, and most of the faculty advisors are your professors in other classes," says Jorgensen. "You have the opportunity to talk to not only your own faculty advisor, who's specialized in the area of your project, but also other faculty with different specializations who might be able to offer tips and advice… This is ultimately great for learning, because design isn't about just knowing one thing. It's about pulling information from a lot of different subjects into one whole project."

All told, BME students graduate with six or seven full semesters of rigorous design experience that is directly transferable to the broader field of biomedical engineering – each project comes from a real client with a real health-related need. Projects can stem from proposals from well-known companies such as Boston Scientific, or they can be as specific as addressing a single need of an individual client. "While there are often some more similar types of projects, each one is ultimately unique," says Puccinelli. Because of the sustained nature of the design program, students get, according to Jorgensen, "that much more tangible experience with the design process, and they are set up much better for success in the future because of it."





Top: CAD drawing of a device intended to be used in a heart surgery. Bottom: 3D printed prototypes of said device and two design variations.

Written by: Patrick Byrne

Photography provided by James Jorgensen

Design by: James Johnston

Using Smartphones to Prevent Traffic Accidents

Through a collaboration between the civil, electrical and computer engineering departments at UW-Madison, a new smartphone app that can help prevent possible traffic accidents may soon be available.

Cellphones are one of the deadliest distractions to use while driving. What if instead of being a source of distraction, smart phones were able to help prevent traffic accidents and make both pedestrians and drivers safer? Kassem Fawaz, an assistant professor in the department of electrical and computer engineering (ECE) of UW-Madison, is seeking to do just that. With the help of colleagues in the civil engineering department and a grant of nearly one million dollars from the Federal Highway Administration, his team is in the midst of developing a smart phone application that can predict traffic accidents and help prevent them.

This project is a completely creative and efficient approach to preventing crashes, which is unique from many other proposed methods. For example, the app runs on data collected from smart devices (such as smartphones), which makes it accessible to many people. Thanks to this innovative use of commonplace technology, the app itself is a very low-cost solution to minimizing possibility for traffic accidents. When compared to the existing Dedicated Short-Range Communications (DSRC) technology, which requires construction of various hardware components on roadsides to help prevent crashes, this proposed project does not need any new infrastructure components, vastly decreasing its cost.

To prevent crashes, a model for pedestrians' behaviors is needed to predict when jaywalking may happen. Professor of civil engineering, Soyoung Ahn, is the lead researcher for this component of the project. The model, professor Fawaz says, will require collecting a series of important, sensitive data such as "GPS location, acceleration sensor [of pedestrians walking] and other IMU (inertial measurement unit) sensors" to be analyzed. This shows yet another advantage of using smart devices for predicting potential crashes, as most phones already have the required sensors. After data collection, the model will utilize machine learning to predict when a pedestrian may start jaywalking, and warning messages then will be sent to the drivers nearby, cautioning them drive carefully. The information will be transmitted via Wi-Fi to nearby devices into voice messages. There are also human factors involved in this information transmission. David Noyce and Madhav Chitturi of the department of civil engineering are working on this aspect to ensure the warning messages will be transmitted to drivers in a non-distracting manner.

"Our vision is installing an app on smartphones to protect the safety of pedestrians"
- Kassem Fawaz

Another crucial part of this project is to ensure the authenticity and security of data. Fawaz points out that not only should each user's information be kept confidential, but also that they want to prevent anyone from abusing the system by sending out false alerts. Fawaz is working on both parts, as data security is one of his specialties. To distinguish authorized users for data authenticity, Fawaz suggests that the app will utilize information such as GPS location, and other sensory data. A sender of beacons must prove that they are a legitimate road user by sending their sensory information along with the beacon. A receiver will correlate the received sensory information and decide whether the message is legitimate or not. Of course, there are several other challenges for establishing this method, such as the networking among users, which Fawaz and ECE professor Parmesh Ramanathan, the leader in this aspect, is hoping to address.

Given the novelty of this research, some weaknesses are still being dealt with in the development of the app. As the sensors of a smartphone will not be able to accurately gauge the size of a human being or a car, it cannot predict at what exact second the crash is going to happen. Rather, this project is aiming to send out warning mes-

The daily commute could soon be made safer through your very own smartphone

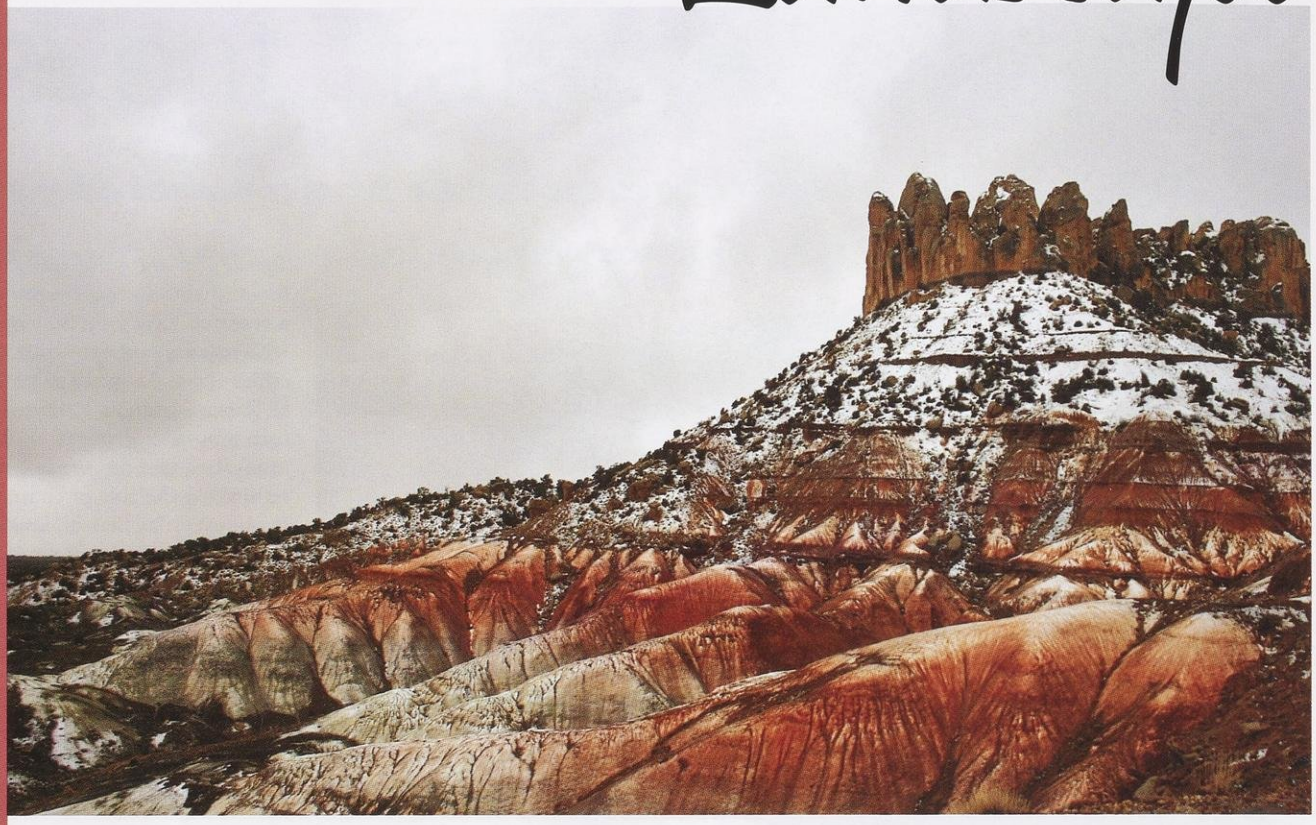
sages to nearby drivers to slow down. In addition, the connectivity of data among users is restricted to some extent. "With roadside units, DSRC has constant connectivity; for this project, we don't have constant connectivity because we are using smartphones," Fawaz says. Due to their power limitations, smart devices have a limited transmission range, and if user distance exceeds this range the app can no longer function.

The app is not quite ready for general use yet. Fawaz mentions that the project is going through a research ethics check, since the app will deal with privacy and data collection. Following this ethics check, Fawaz expects that this project will be finished in about four years. This app will help turn a possible cause of traffic accidents into an innovative tool for preventing them, completely rethinking the role of commonplace technology in our everyday lives and making our roads safer for everyone. The most powerful new technology for road safety may be in your pocket.

Written by: Daniel Yao
Photography by: Hamoud Alshammari
Design by: Isabella Wegner

The Wisconsin Engineer's 11th Annual Photo Contest

Landscape



Category Winner - Grand Staircase - Matthew Barrett

Runner-Up - The Peak of Hochwanner - Mek Sudhiwana

Still Life

The Wisconsin Engineer's

11th Annual Photo Contest

Category Winner - Wreckup Pickup - Laith Abdulmajeid

Runner-Up - Marrakech Market - Haley Winckler

The Wisconsin Engineer's 11th Annual Photo Contest

Portrait

Category Winner - Icelandic Horse - Josh Redfearn

Runner-Up - Even Dogs Love Lake Mendota Sunsets - Tyler McRoberts

Miscellaneous

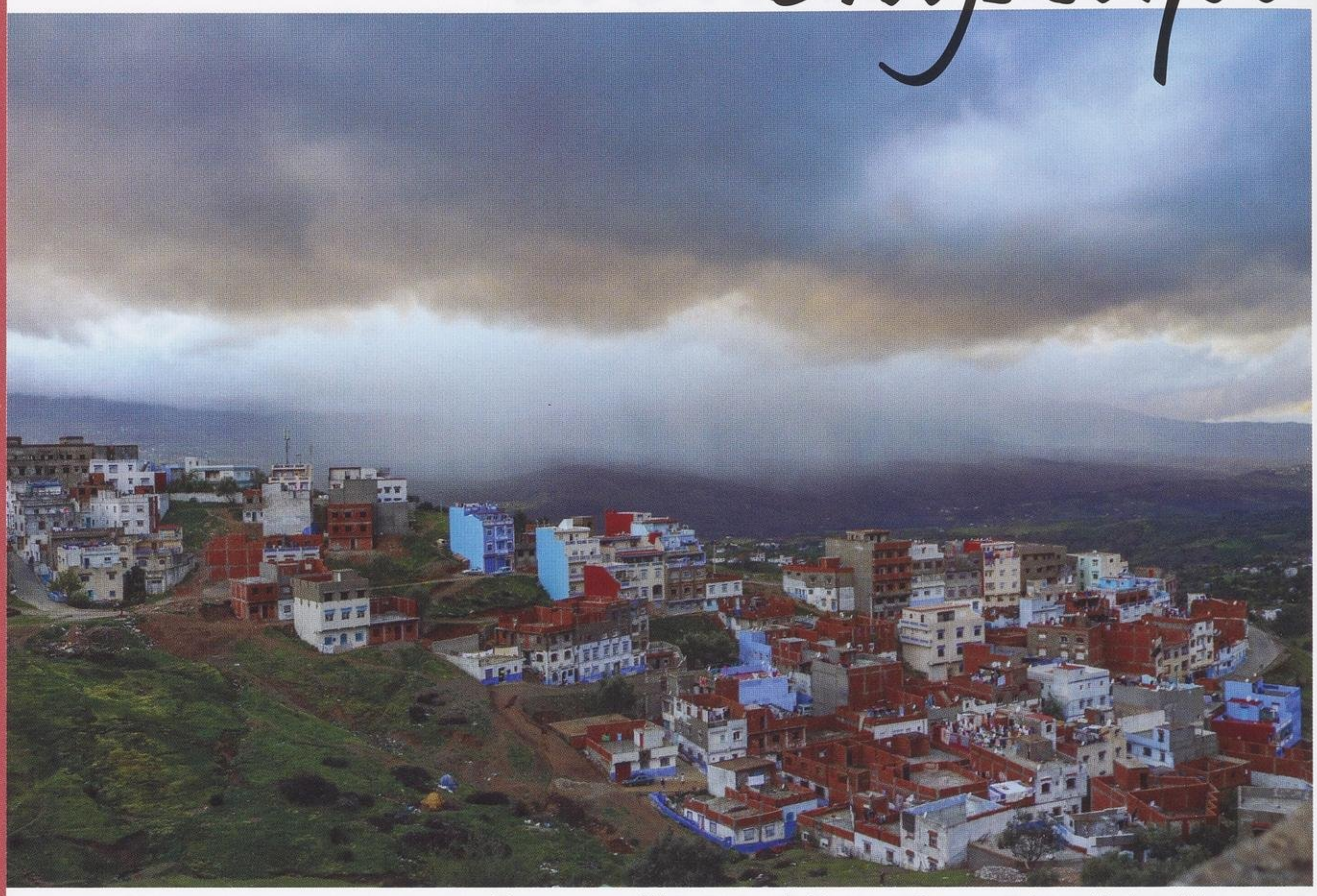
Category Winner - Starry Night - Seth Gehrke

Runner-Up - Lake Michigan Queen's Cup Race - Joseph Harter

The Wisconsin Engineer's

11th Annual Photo Contest

Cityscape



Category Winner - A Storm Descends - Haley Winckler

Runner-Up - Shinjuku Street - Josh Emory

The Code of Conversation

How machine learning and artificial intelligence are allowing an unprecedented understanding of human language

Machines are often viewed as the antithesis of everything sentimental and human. The scope of a computer's work has appeared to be limited solely to problems of lifeless computation or uninformed, mechanical number crunching. But while computers historically have not had much say in matters like therapy or communication, today's rapid development of machine learning and artificial intelligence (AI) means that all of that is about to change.

"We should not be fearing these big data learning techniques. We should embrace them and try to get the best out them."

- Prathusha Sarma

Contributing to this revolution is Prathusha Sarma, a PhD student at the University of Wisconsin-Madison studying Natural Language Processing and Machine Learning. She has developed a way to produce "domain adapted word embeddings" (as the technique has been officially coined in her paper) from text-based conversation. In essence, she has worked to create an algorithm that can read from sources like tweets or text conversations and then make judgements about a person's attitudes or sentiments after analyzing the connotations of what that person had said. But how is a computer able to grasp the subtleties of human language?

It turns out that all words can be mapped to their own unique vector in space, and that each of these vectors carry valid information about the meanings of the words they represent. Professor William Sethares from the Electrical and Computer Engineering department, who has overseen Sarma's work, explains that when two translated words end up pointing in the same direction, it can be assumed that they share similar meanings. For instance, synonyms like "look" and "see" would likely present with similar spatial orientations whereas the word "man" with respect to "woman" might point perpendicularly. Traditionally, this process of word-embedding has been achieved with the use of resources like word2vec or GloVE (computer models, or code, that "learn" the pattern for projecting words into space after being fed large amounts of data).

The feats of these algorithms alone are amazing, as they allow us to draw a substantial number of quantitative conclusions about language. However, the concern with these models is that they train on words obtained mostly from extremely general sources of text like Wikipedia. This doesn't bode well for words that take on a specialized meaning within different contexts. As Sarma explained, the word "party" could be viewed as a neutral term in everyday speech, but amongst individuals who suffer from substance abuse and addiction, it can have highly negative implications.

In fact, this is the exact problem that Sarma and her group originally set out to solve. Working in conjunction with the Center for Health Enhancement System Studies (CHESS), the goal was to figure out how disparities between the general use of certain words and the use of those words within the Substances Users Disorder (SUD) community could be accurately represented. Specifically, what types of conversation signal that person is at a greater or lower risk of relapse. Sarma's novel variation on the vectorization technique described above which accounts for these kinds of distinctions is referred to as "domain adapted" embedding. In her edition of word embedding, the correlation between two regular sets of vectors is visualized by mapping each group into their own, unique space. You could think of this new projection as a weighted average of the two sets, the weights of which get processed by a computer so that it can eventually learn how to classify not only the data that it's currently being trained on—it could also classify any new data that it might ever be thrown in the future.

By discovering a method that can interpret words so pre-

Professor William Sethares

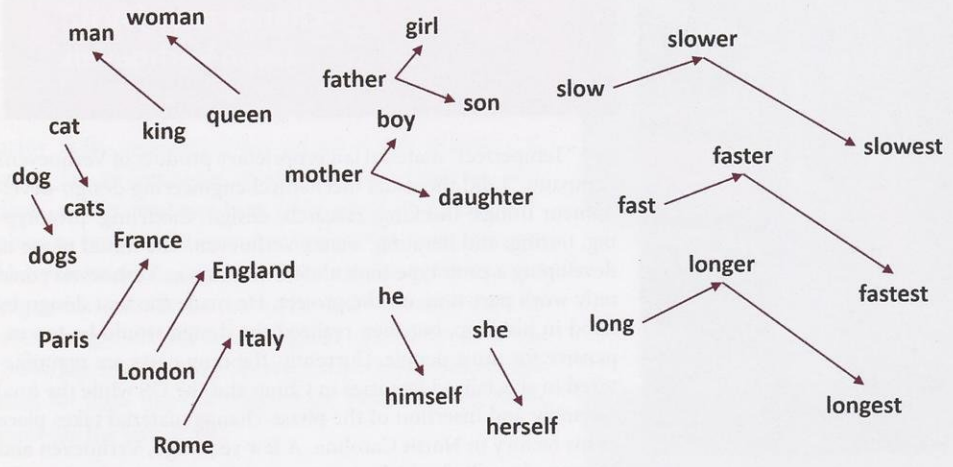
cisely and do so with relatively small sets of data (another challenge that arises when working with specialized domains), Sarma has opened the doors to a new, improved way of processing language. While the initial purpose of her project was to help distinguish healthy individuals from those facing a potential relapse threat, it has since found a purpose in other realms as well. According to Sarma, it was because of Professor Dhavan Shah from the University of Wisconsin-Madison's School of Journalism that the application of her algorithm towards measuring political polarization is currently under review. After embedding a stream of about 1,000 tweets each from Democrats and Republicans, the group was able to observe how the same word could produce a vastly different vector. The words that measured up to have the most dissimilarity were words that a person would expect to be polarizing, such as "abortion" or "immigration." This reiterates that there is clearly a validity to these comparisons; they are not just baseless quantifications. And this is just the beginning for Sarma's work. Another group of students are even using it to measure meme virality, investigating how variation in word usage can indicate how something becomes a meme.

So, what does having all of this knowledge mean? Well, that's up to us.

Right now, the main accomplishment is the ability to study trends like this in the first place. The types of questions currently being asked are along the lines of "what is characteristic of an at-risk individual?" or "how has political divisiveness evolved time?" That being said, the information available now is only part of the story. Sethares mentions that next immediate step might be learning to extract chains of influence as well. Then we can start to approach questions like: What leads a person to becoming considered more at risk? What really causes someone to lean more liberal or conservative? Eventually, when we can move beyond this stage, this information will hopefully be able to inform real action and intervention. For example, perhaps we analyze headlines and promote moderate titles over extremely partisan ones. Or maybe we alert sponsors to check in with their sponsees whenever they're engaging in troubling conversation. It's truly a blank check.

By learning how to quantify and interpret something as elusive as language, we wield a power over it like never before. Problems like addiction and partisanship, while certainly not fully resolved, seem a little bit less helpless this way, as technology is bringing to light connections that we might have elsewise never known existed. After all, when we have the numbers, we have a way to talk about an issue—something to work from. Like Sarma insists, "We should not be fearing these big data learning techniques. We should embrace them and try to get the best out them." No matter where this field takes us—whatever direction it points us to—there's no denying that machine learning has forever transformed the role of computers and the way we think about this world.

Read the complete paper "Domain Adapted Word Embeddings for Improved Sentiment Classification" by Prathusha K Sarma, Yingyu Liang, and William A Sethares



This is a depiction of linguistic vector space for sentiment analysis

Written by: Brianna Tobin

Photography provided by ECE Department

Design by: Patricia Stan

A Temperfect Invention

UW-Madison alumnus Dean Verhoeven has ingeniously used a natural phase-changing material to create a better travel mug: the Joeveo Mug

The ideal receptacle for your beloved hot beverage

It happens to everyone: you're in the process of reaching for a travel mug for a sip of your favorite hot beverage when it either burns your tongue or it hits your mouth at an unsatisfying room temperature. To solve this common problem, UW-Madison alumnus Dean Verhoeven has created a revolutionary phase-changing material to produce the Joeveo mug.

Most mugs feature a double layer of stainless steel with a layer of insulation between them. The Joeveo mug features three lays of stainless steel with two layers of insulation, with the innermost layers holding the "Temperfect" insulation. "Temperfect" is a non-toxic waxy substance resembling canning paraffin. "I was frustrated that I couldn't drink my coffee right away after making it because it was too hot, and that it got cold before I had a chance to enjoy it," Verhoeven explains. To this end, the material melts within the stainless-steel layers at 60°C/140°F, the perfect drinking temperature, and then releases the heat back to the drink as it cools, maintaining an optimal temperature for hours.

"I was frustrated that I couldn't drink my coffee right away after making it because it was too hot, and that it got cold before I had a chance to enjoy it."
- Dean Verhoeven

The "Temperfect" material is a proprietary product of Verhoeven's company. "I did the usual mechanical engineering design-development things: thinking, research, design, modeling, prototyping, testing, and iterating," states Verhoeven. The initial phase of developing a prototype took almost 15 years as Verhoeven could only work part-time on the project. He made the first design by hand in his shop, but then realized the design would be too expensive for most people. Currently, the mug parts are manufactured in specialized factories in China and the US while the final assembly and insertion of the phase-change material takes place in his factory in North Carolina. A few years ago, Verhoeven and his team launched a kick-starter campaign to begin funding the project. Since this campaign the company has expanded, currently they have sold over 6000 mugs.

At a young age Verhoeven aspired to study mechanical engineer-

ing and he followed his dream by earning his undergraduate degree from UW-Madison. Verhoeven stayed at UW-Madison to complete his masters and develop laser-based measurement techniques in the Engine Research Center. Thereafter, Verhoeven received a scholarship to study in an engine research lab in France where he earned his PhD. Currently he uses his attained knowledge from UW-Madison to redesign simple household items, "I don't think there is anything I learned at Madison that I haven't used for the Temperfect mug project: thermodynamics, heat transfer, materials science," says Verhoeven.

After 15 years of product development, Verhoeven has put all of his mechanical engineering skills to the test. Over the course of his career, Verhoeven has honed his many skills, including those gained at UW-Madison, to create his revolutionary invention. Like Verhoeven, students at UW-Madison have been gifted many opportunities to involve themselves in ground-breaking research and placement in extraordinary companies. Verhoeven began his journey in the same desks current students now occupy. As did Matt Younkle, the inventor of the TurboTap, and Dr. Fritz Bach who developed a technique used for bone marrow transplants. What will you do to innovate the world?

Sip your caffeine at an optimal temperature from dawn til dusk.

Written by: Makenna Hall

Photography provided by Dean Verhoeven

Design by: Laura Rodricks

Reevaluating Carbon Efficiency in Biofuels

To determine the best possible approach to produce biofuels, we need to take a more holistic approach that examines all three parameters: carbon efficiency, fuel quality, and energy requirements.

"We have to consider more than just carbon efficiency when choosing the best option for biofuel production."

– Christos Maravelias

Many governments around the world have been researching renewable energy sources in response to growing public concern over environmental impact of conventional energy sources such as coal. Not too long ago, the word "biofuel" was unfamiliar to the public ear. In recent years, however, it has cultivated its reputation as one of the most prominent types of renewable and environmentally-friendly sources of energy.

Of the variety of biofuels available today, ethanol is the most popular. Currently, much of the gasoline in the United States is blended with ethanol. This high popularity of biofuels stems from the massive presence of raw materials, such as corn or wheat. The vast numbers of these materials as well as a rapid increase in demand for energy makes biofuels even more lucrative for various governments. As a result, various researchers are trying to advance the technology to maximize the efficiency of biofuel production.

Initially, optimizing carbon efficiency was thought to be the most critical factor in producing biofuels. This assumption meant that it was better if more carbon from corn crops ended up in fuel. However, research has shown that this is not always the case. According to Professor Christos Maravelias, Vilas Distinguished Achievement and Paul A. Elfers Professor of chemical and biological engineering at UW-Madison, other factors such as fuel quality and energy requirements for the conversion of biomass to fuels in the biorefinery play an equally crucial role in biofuel generation.

Maravelias and his team from the Great Lakes Bioenergy Research Center are funded by the United States Department of Energy to research the optimization of carbon efficiency. The goal of this specific project, however, is not to determine the most promising strategy to produce biofuels, but rather to identify the critical aspects that must be taken into account for this strategy's eventual development.

In their analyses, the Maravelias lab chose to draw comparisons between two different processes to produce biofuels: biological conversion to ethanol (BCE) and catalytic conversion to alkenes (CCA). In order to objectively gauge how effective these two processes are in terms of producing the "best" type of biofuels, the researchers use the mechanical energy necessary for transportation as the quantitative point of comparison, as mechanical energy directly reflects the amount of fossil fuels that can be replaced by biofuels. In addition to the energy from the fuel, electricity can be used as a source of energy. Electricity is the byproduct of the conversion of corn crops to biofuels in a biorefinery in which the waste of the process (mostly lignin) is burned.

The result of this research showed that despite the higher carbon efficiency in the ethanol produced with BCE, the fuel itself leads to lower fossil fuel replacement compared to the fuel produced in the CCA strategy. This is because alkenes produced in the latter are burned in automobile internal combustion engines. After factoring in the amount of electricity into their calculations, Maravelias and his team found out that the CCA process produces almost 60 percent more mechanical energy than the BCE process. This result proves that carbon efficiency is not the only important parameter for production of biofuels. Fuel quality and energy requirements are also important in the formulation of the best method to determine the next-generation biofuels.

Maravelias intends to continue developing models to study biomass-to-fuel strategies and hopes that this research will illustrate that a more holistic, systems-level approach is necessary when studying biofuel strategies. He remains optimistic that future scientific and technological advances will lead to cost reductions which will make biofuels a stronger substitute for traditional fuels.

Written by: Alfred Sunaryo

Design by: Patricia Stan

The Small but Mighty Catalysts

In the face of big problems such as environmental pollution and increasing energy demands, catalysts are tiny substances which are making a huge difference.

Though catalysts may be small, they are a vital component in the production of many everyday items. These microscopic powerhouses not only increase the rate of chemical reactions– they also help reduce environmental pollution associated with production in chemical plants and car emissions. These particles may be small, but they are mighty.

Professor Manos Mavrikakis and his team in the chemical engineering department at UW-Madison study catalysts, substances which increase the reaction rate of a chemical reaction. One major benefit of using catalysts is that they remain unconsumed during the reaction. This eliminates the worry of ending up with an unexpected catalyst-containing product.

Catalysts are a particularly relevant area of chemistry for research because of their extremely wide range of applications. "Ninety percent of products we encounter in our lives as humans are produced with catalysts," says Mavrikakis. The common plastic grocery bag is a perfect example of this. Grocery bags are made by catalytic processing of petrol to form ethylene gas, which is highly energy-intensive. "My work is very prevalent and very widespread," says Mavrikakis, elaborating on the predominance of catalytic production.

Professor Mavrikakis spends his time researching catalysts because of their efficacy in chemical reactions. If he can develop a faster catalyst or even improve existing catalysts, he can reduce the amount of energy required for a chemical reaction. "In addition to making chemicals and fuels, catalysts are very important to ameliorating environmental pollution. The catalysts will lower the energy needed to make a chemical transformation. By finding better catalysts, you're helping the environment, so you do not need to produce and use so much energy," says Mavrikakis. Large chemical plants would require less energy for many chemical processes if scientists can find better catalysts.

"Ninety percent of products we encounter in our lives as humans are produced with catalysts."
- Manos Mavrikakis

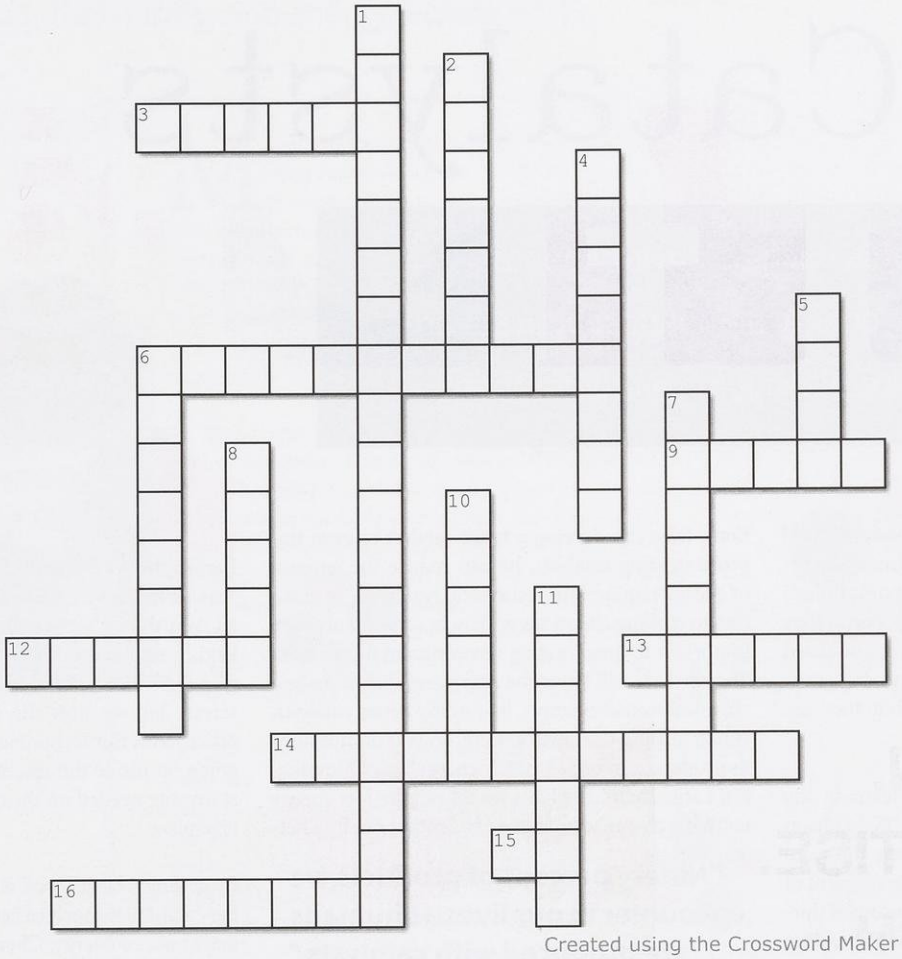
Catalytic processes are not only energy consuming– they can also be costly. This is because catalysts tend to be rare metals, such as platinum or rhodium. Mavrikakis' next step is finding a way to utilize these precious materials as efficiently as possible. The catalyst with a larger surface area can reach more chemicals in a reaction, which means less catalytic material is wasted in the interior of the particle. "If I can figure out how I can study individual atoms so that all the atoms in the particle are highly dispersed, then all of the expensive atoms can be used in catalysis. That is my major goal," says Mavrikakis.

Earlier this year Mavrikakis was recognized by the American Chemical Society with the Gabor Somorjai Award for Creative Research in Catalysis. Mavrikakis' research group used computer techniques that allow scientists to create a molecular structure on the screen and see how the molecules react with each other. With this technology scientists can see what is going on inside the reaction and the "nature" of the active site needed on the catalyst for the reactions to take place.

By getting a closer look at the atomic scale, improving catalysts is much easier. This all leads to more efficient use of energy. Chemical plants are just one of the many industries that could reduce energy costs and environmental hazards with more efficient catalysts.

Written by: Camey Zussman
Design by: Isabella Wegner

THE ENGINEERS' CROSSWORD



Created using the Crossword Maker on TheTeachersCorner.net

cross

3. The twisting or rotational force on an object.
6. Brain region associated with the formation and consolidation of memories.
9. A gas that only undergoes elastic collisions is consider to be _____.
12. A solution that resists changes in pH when an acid or a base is added to it.
13. Well known scientist credited with the development of calculus.
14. _____ occurs when two or more waves interact with each other, either constructively or destructively.
15. The abbreviation to describe the ability of a machine to seemingly replicate the human thought process.
16. _____ motion can describe the random movement of particles within a fluid.

Down

1. Transmitting a signal by varying the frequency of a carrier wave. Used in FM radio.
2. Third lightest element commonly used in batteries.
4. A device having a designed resistance to the passage of an electric current.
5. Object-oriented programming language known for "running everywhere" and used in Android development.
6. The amount of time it takes for half of an unstable element to decay.
7. A scientist known for developing the theory of relativity.
8. The time-rate of doing work, measured in watts, or less frequently, horsepower.
10. A _____ counter can be used to measure radiation.
11. Inability to recall or form long-term memories.

Design by: Eric Shumaker, and James Johnston

Solutions can be found at: wisconsinengineer.com/crossword

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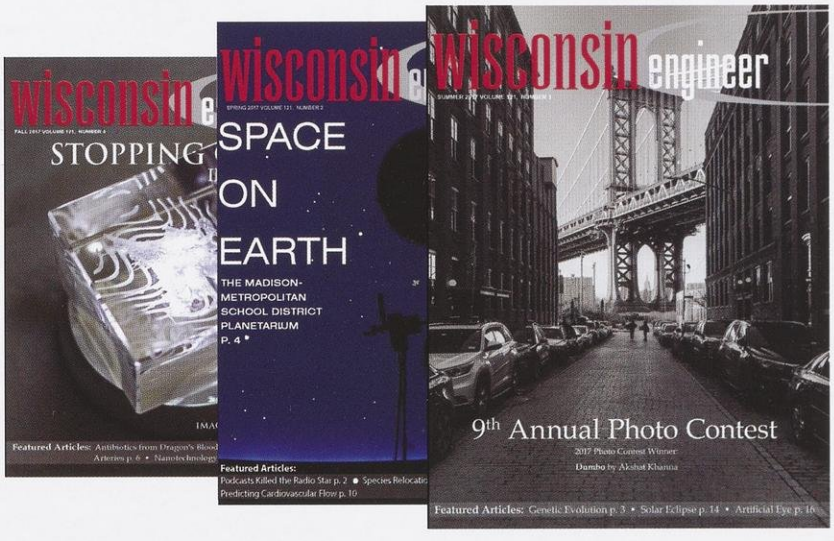

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