SPRING 2018

CHEMICAL AND BIOLOGICAL ENGINEERING

UNIVERSITY OF WISCONSIN-MADISON

BUILDING BLOCKS FOR A BETTER POWER GRID

CHAIR'S MESSAGE

Manos Mavrikakis

Greetings from Madison!

As we are approaching the end of the Spring 2018 semester, please join me in congratulating 73 CBE undergraduates graduating this semester. We look forward to observing how each of these students will make an impact in their career as a result of their highest quality training in CBE.

Starting out with some very exciting news from our alumni, and continuing with the long-standing tradition of excellence, **Raymond Gorte** (BS ChE '76), a member of the CBE faculty at the University of Pennsylvania, was recently elected to the National Academy of Engineering (NAE). Ray's election recognized his fundamental contributions and their applications to heterogeneous catalysis and solid state electrochemical devices. We are very proud of Ray.

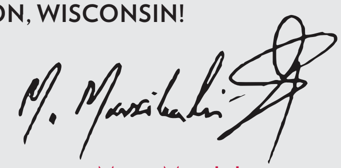
Faculty news includes **Victor Zavala**'s receiving the very prestigious CAREER Award from the National Science Foundation (NSF). Victor is planning to study the impact of modular technologies on diverse systems such as the national power grid and agricultural supply chains. Clearly, not a mainstream type of research for chemical engineering, but an example as to how our faculty opens up new research areas by leading research in fields not necessarily central to chemical engineering. Further, the College of Engineering recognized **Regina Murphy** with the Benjamin Smith Reynolds Award for Excellence in Teaching Engineers. Regina has worked diligently to modernize the delivery of many of the courses she teaches, including the implementation of active-learning methods. Our distinguished faculty associate, **Andrew Greenberg** was awarded the Equity and Diversity Award from the College of Engineering for developing unique research experiences and mentor training exercises that have each played a significant role in the department's ability to recruit and retain underrepresented minorities. To wrap up CBE's esteemed awards, we are proud to recognize **Daniel Klingenberg**'s receiving a 2018 Chancellor's Distinguished Teaching Award. This very competitive award recognizes the finest UW educators year after year, since 1953.

One of the several newsworthy research stories coming out of CBE this semester, illustrates the power of collaboration between various kinds of expertise in the department. In particular, **Reid Van Lehn**'s expertise in statistical mechanical simulations, in collaboration with catalysis experts **George Huber** and **James Dumesic** led to a significant advance, whereby the effect of solvent in biomass conversion reactions has been elucidated quantitatively. This pioneering work was published in the journal *Energy & Environmental Science*. With these findings, researchers can directly estimate reaction rates of newly designed biomass conversion processes from the solvent composition, without having to perform a series of expensive and time-consuming experiments.

In student news, **Nathan Wang** a CBE junior, was named a 2018 Barry Goldwater scholar. Nathan's scholarship is in recognition of his outstanding academic achievements and experience working in research laboratories at UW. The prestigious Barry Goldwater scholarships are awarded to undergraduates who intend to pursue careers in engineering, the natural sciences or mathematics. In addition, two of our PhD students **Benjamin Gastfriend** and **Curran Gahan** have each received a National Science Foundation Graduate Research Fellowship. **Kristen Lemke**, an alumna, also received this very competitive award. The NSF Graduate Research Fellowship Program recruits high-potential scientists and engineers and supports their graduate research training in STEM fields.

This is the last CBE Newsletter we are putting together before I step down as the Department Chair. It has been a great honor to lead this historic Department. The last three years were full of unique experiences for me, which I will cherish throughout my career. I have been very fortunate to meet many of our alumni in person and experience first hand their passion for the well-being and competitiveness of their alma mater. Despite the challenges, faculty and students continue working hard to distinguish themselves at the National and International landscape, and the results of these efforts are recognized many ways on a regular basis. Support from the alumni has been an essential enabler and will continue to play an increasingly important role in the future. Given our collective commitment to academic excellence in both the teaching and research mission of the Department, I am confident we are going to keep the Wisconsin flag flying high!

ON, WISCONSIN!



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MAKING THE MOST OF MODULARITY: VICTOR ZAVALA EARNS PRESTIGIOUS NSF CAREER AWARD

Drawing inspiration from evolutionary biology, power networks, and Henry Ford's assembly line, Victor Zavala plans to develop optimization frameworks to understand the impacts of modularity on the performance and resilience of complex systems.

With support from a prestigious CAREER award from the National Sciences Foundation, Zavala, the Richard H. Soit Assistant Professor, will attempt to study the impact of modular technologies on diverse systems such as the national power grid and agricultural supply chains. The concept has other far-reaching applications, though.

"Modularization is a general organizational principle that applies to a lot of things," Zavala says, noting that he dipped his toes into such far-reaching fields as brain networks and corporate sociology to familiarize himself with how living systems and organizations use modularity to cope with complexity. "What I have found is that complex systems tend to naturally organize in a modular manner, but they exhibit very different degrees of modularity."

Modular systems can benefit from economies of mass production, a perk made famous by Henry Ford. For instance, each portion of an automobile can be assembled separately (in a decentralized manner) so that workers can experiment over and over again in their subsystem to reach a high level of technical maturity.

An entirely decentralized system is not always desirable, however, because centralized systems benefit from economies of scale, or the higher efficiencies that larger systems achieve.

Striking the correct balance between economies of scale and economies of mass production can be tricky, especially because few tools exist to quantify how modular a system is compared to another.

Zavala intends to create optimization formulations and algorithms to do just that.

"This is the right time for the development of modular technologies, because 3D printing and automation have made it easier than ever to create such systems," says Zavala.

In the context of power grids, Zavala notices that major advances in decentralized energy technologies like photovoltaic panels and batteries have been achieved, but centralized power plants still deliver electricity at a lower cost. Unfortunately, centralized systems are also susceptible to disruption—for example, heat waves or cold fronts can overtax large power facilities and cause widespread blackouts.

"There are complex trade-offs between how expensive you want the power to be and how resilient you want the power grid to be," says Zavala.

The notion that modularity might make for more resilient systems has been well-studied in biological sciences. From ecosystems to developing flies, life scientists observe that innovation thrives among collections of connected but independent components—like the small communities of animals in a swamp or an insect's body segments.

"Scientists have noted that modularity is a key property that enables evolution," says Zavala.

Zavala also plans to use modularity to help undergraduate education evolve. In collaboration with Professor Thatcher Root, he will seek to reengineer the semester-long undergraduate introductory statistics course into a series of three modules. By modularizing the class, Zavala hopes to create better coordination between the abstract statistical concepts being taught and their applications in students' other engineering coursework.

The grant provides $500,000 of support over five years.

"What I have found is that complex systems tend to naturally organize in a modular manner, but they exhibit very different degrees of modularity."

FOR UNDERSTANDING TURBULENCE, THE SKY IS THE LIMIT

Mike Graham's turbulence research could help pave the way for advanced airplane wings or better weather forecasting.

View a satellite image of a hurricane and you'll quickly realize how pervasive and powerful turbulence can be.

Beyond superstorms, understanding the dynamics of swirling fluids could help engineers improve everything from airplane wings to artificial organs—and yes, even predicting the weather.

Michael Graham is a leader in this type of research, and a recently awarded U.S. Department of Defense Vannevar Bush Faculty Fellowship is enabling this potentially transformative turbulence research.

"This is a big opportunity to integrate fundamental ideas with applications," says Graham, the Vilas Distinguished Achievement Professor and Harvey D. Spangler Professor.

Given that turbulence causes drag, which is a major concern for airplane design, Graham's work could lead to faster jets—and insights into how different geometries shape turbulence patterns might also help usher in more fuel-efficient cars. Turbulence also plays a role in global climate, as a major mixer for the air that shuttles heat between Earth's surface and the upper layers of the atmosphere.

Yet even though turbulence is present in almost every fluid moving near a surface, scientists still don't understand many basic features about what causes flows to develop dramatic swirls and whirls.

Graham's ambitious project attempts to increase that understanding. It runs the gamut—from basic theoretical research to applied problems.

With $3 million of support spanning five years, Graham and colleagues will take a deep dive into the dynamic forces that control turbulence, which roils almost every moving fluid on the planet, from air in the atmosphere to blood circulating in human veins.

The team will work out new mathematical models for describing flow dynamics. The researchers will also train machine-learning algorithms to predict turbulent behavior.

Armed with new theoretical knowledge, the researchers will develop turbulence manipulation strategies to fine-tune fluid flow.

The motion of turbulent fluids seems entirely random, at first glance, but structured repeating patterns do emerge over time. The interplay between predictable structure and random motion has long made turbulence one of science's greatest mysteries.

"We still don't know many things, like how to manipulate flow to reduce drag," says Graham.

Graham's research builds on his expertise in using advanced computational and theoretical approaches to understand turbulence. He will make those computational models even more formidable by leveraging machine learning, a powerful tool for parsing patterns to predict future outcomes.

"I'm excited because the Department of Defense is really encouraging scientists to follow their curiosity," says Graham, who was selected as one of 11 new fellows for 2018. "Because our work is very fundamental, it could be applicable in many different situations."

FRESH PERSPECTIVE ON BIOFUELS RESEARCH COULD OPTIMIZE PRODUCTION

Photo: Stephanie Precourt

Assistant Professor Reid Van Lehn's expertise in protein simulations—a research area normally beyond the horizon of the biofuels world—led to an innovative research project with his colleagues and renowned biofuels experts George Huber and James Dumesic.

"I think our study paves the way for optimizing biofuel production processes in the future by providing fundamental insights into the reaction pathways and developing methods for predicting their properties," Van Lehn says.

The study is innovative for two reasons. It applied molecular dynamics simulations, which are often used for studying how proteins fold into 3D structures, to biomass-derived molecules, an entirely different class of chemicals. It also combined three particular quantities derived from these simulations in a statistical model that predicted, with high accuracy, the experimentally observed reaction rates.

Therefore, an entire class of reactions can now be analyzed in a much more high-throughput way, compared to the detailed theoretical calculations that had been used for one specific reaction in the past.

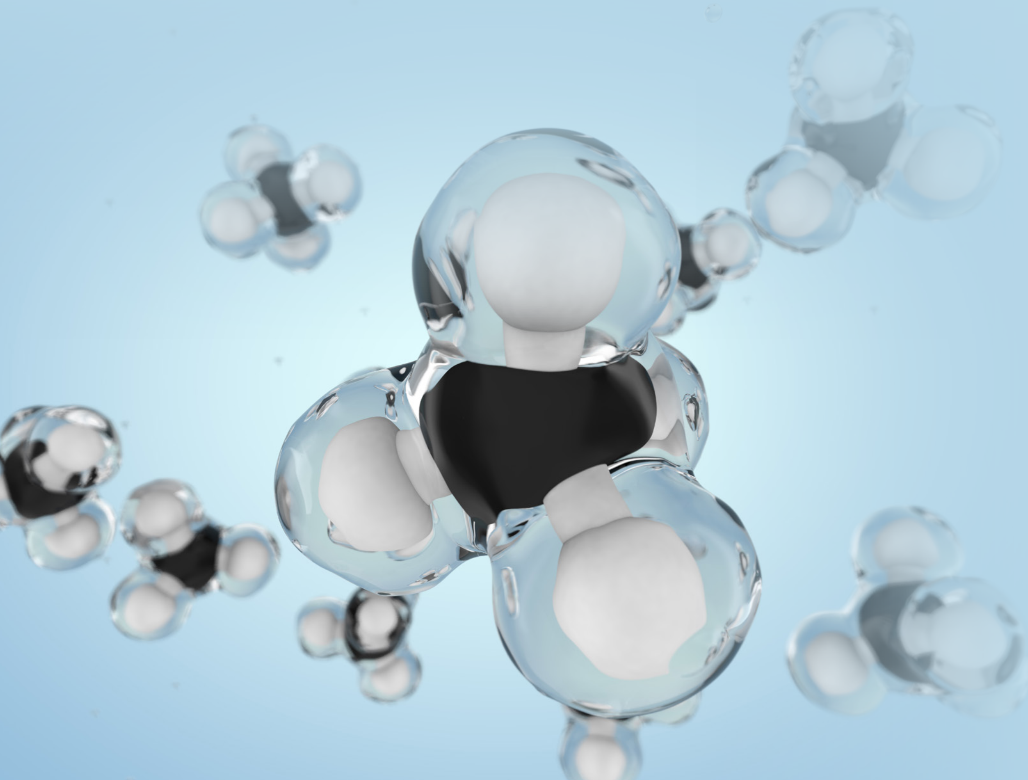
"What's most exciting to me is that we can accurately predict these increases with computational models of atomic-level interactions between the reagents," says Van Lehn.

The researchers focused on a class of reactions that break down biomass by dissolving it in a mixture of water, a cosolvent, and an acid catalyst. By modeling how tens of thousands of atoms move and interact with each other, they showed that the cosolvent speeds up the breakdown by concentrating water molecules in the physical space around the biomass molecules where the catalyst is active.

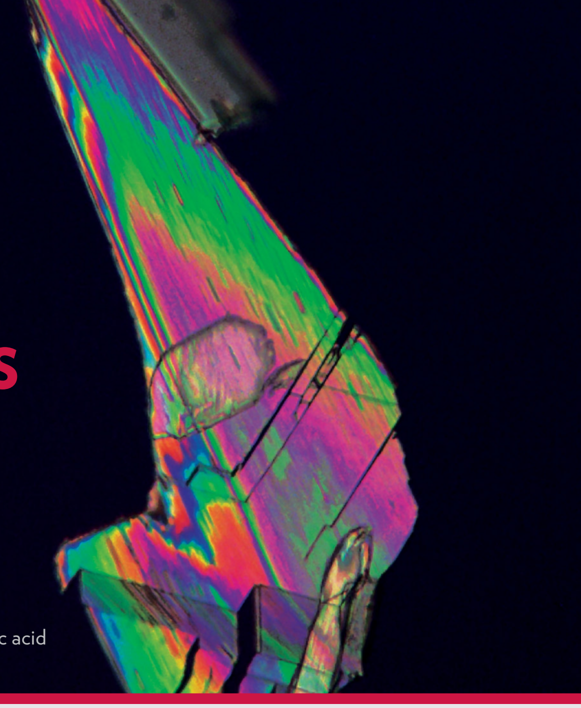
With these models, published online on Feb. 8, 2018, in the journal *Energy & Environmental Science*, researchers can directly estimate reaction rates of newly designed biomass conversion processes from the solvent composition, without having to perform a series of expensive and time-consuming experiments.

Going forward, they also hope to broaden the scope of the methods applied in this study to predict entire biological pathways, which could improve the design of drug delivery vehicles in medical applications.

The paper's lead authors were PhD students Theodore (Ted) Walker, who is advised by Huber and Dumesic, and Alex Chew, who is advised by Van Lehn.



SWEET NEW SUGAR-TO-PLASTICS STRATEGY SHOWS PROMISE



A crystal of furandicarboxylic acid

James Dumesic

Plastics are an abundant part of daily life, but being derived from petroleum, the materials contribute to reliance on fossil fuels and harmful greenhouse gas emissions. James Dumesic, the Ernest Micek Distinguished Chair, is trying to take the pliable nature of plastic in another direction, developing new and renewable ways of creating plastics from biomass.

Using a plant-derived solvent called gamma-Valerolactone, Dumesic and his team have developed an economical and high-yielding way of producing furandicarboxylic acid, one of 12 chemicals the U.S. Department of Energy calls critical to forging a "green" chemical industry.

The researchers published their findings Jan. 19, 2018 in the journal *Science Advances*.

Furandicarboxylic acid is a necessary precursor to a renewable plastic called polyethylene furanoate, as well as to a number of polyesters and polyurethanes. Polyethylene furanoate is the bio-based substitute for polyethylene terephthalate, which currently has a market demand of close to 1.5 billion tons per year.

Coca-Cola, Ford Motors, H.J. Heinz, Nike, and Procter & Gamble have all committed to developing a sustainably sourced, 100-percent plant-based plastic for their bottles, packaging, apparel, and footwear. Polyethylene furanoate's potential to break into that sizeable market, however, has been hampered by the high cost of producing the precursor.

"Until now, furandicarboxylic acid has had a very low solubility in practically any solvent you make it in," says Ali Hussain Motagamwala, a CBE graduate student and co-author of the study. "You have to use a lot of solvent to get a small amount, and you end up with high separation costs and undesirable waste products."

Motagamwala and colleagues' new process has a high yield and easily separates from the solvent as a white powder upon cooling.

The team's techno-economic analysis suggests that the process could currently produce furandicarboxylic acid at a minimum selling price of $1,490 per ton. With improvements, including lowering the cost of feedstock and reducing the reaction time, the price could reach $1,310 per ton, which would make the material cost-competitive with some fossil fuel-derived plastic precursors.

"We think this is the streamlined and inexpensive approach that many people in the plastics industry have been waiting for," says Dumesic. "Our hope is that this research opens the door even further to cost-competitive renewable plastics."

The Wisconsin Alumni Research Foundation is working to license the technology for use in bioplastics production.

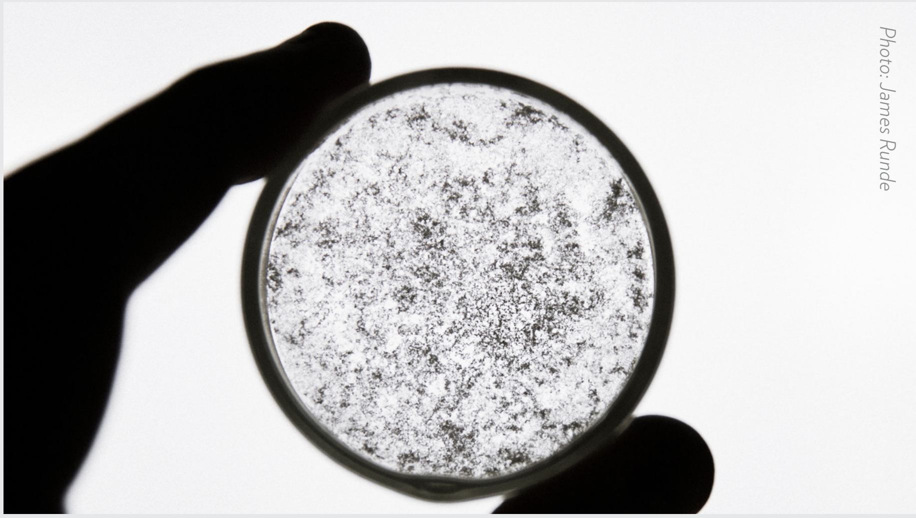


Photo: James Runde

A renewable process for creating a plastic precursor could improve the economics of making plastic from biomass.

ROADMAP FOR METHANE TO PLASTIC COULD MAKE NATURAL GAS MORE GREEN

The majority of natural gas is currently used for electricity generation, heating, and cooking, and only 1.5 percent is converted into the chemicals that make plastics, adhesives, and other consumer products. Converting more methane into commodity chemicals could further reduce the energy sector's contribution to global warming. And chemical engineers have developed a framework for evaluating less complex and costly methane-to-chemicals conversion strategies that help realize more environmental benefits for natural gas.

"Recent findings have sparked an interest in simpler reactions that don't require oxygen and generate less carbon dioxide as a byproduct," says Christos Maravelias, the Vilas Distinguished Achievement Professor and Paul A. Elfers Professor. "Our study provides a roadmap that highlights the technology gaps our research community has to fill so that companies will consider putting these newer non-oxidative methane conversion processes into practice."

The study, published online Jan. 23, 2018 in the journal *Joule*, goes well beyond studying reaction and separation systems in the lab. It considers the entire series of steps—and their associated costs—that make up a commercial process, from the initial methane reaction to separating and storing the desired products to recycling unreacted methane.

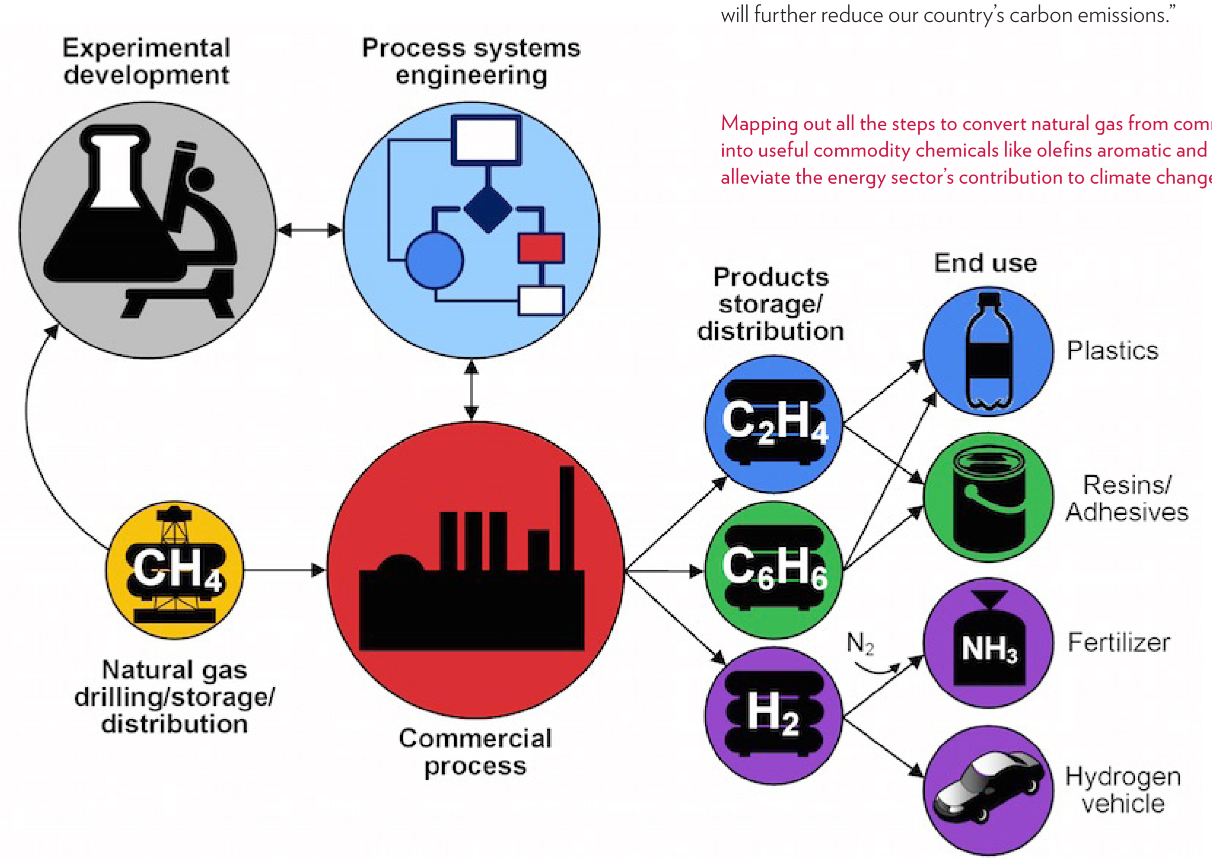
"Modeling a multi-step process that reflects the complexity of a real system was challenging, but we wanted our results to be useful for other researchers," says Kefeng Huang, a postdoctoral fellow in Maravelias' lab who is the paper's first author.

One of the study's main findings is that future research should focus on two key areas: a first-pass methane conversion rate above 25 percent and a catalyst "coking" percentage below 20 percent.

"Coking is the formation of carbon residues on the catalyst," Huang says. "It reduces its chemical activity, which slows down the reaction of interest, and reduces the fraction of carbon that is converted into ethylene or other desirable end products."

Achieving these kinds of process improvements is no small feat, but the first step is an awareness of the biggest knowledge gaps.

"We have outstanding researchers in the area of catalysis, including my colleagues and co-authors," Maravelias says. "That's why I'm confident that scientific advances, whether they involve reduced manufacturing costs of catalysts, better performance, or both, will allow us to use a greater percentage of natural gas as a feedstock for commodity chemicals, which will further reduce our country's carbon emissions."



Mapping out all the steps to convert natural gas from commercial processes into useful commodity chemicals like olefins aromatic and hydrogen could help alleviate the energy sector's contribution to climate change.

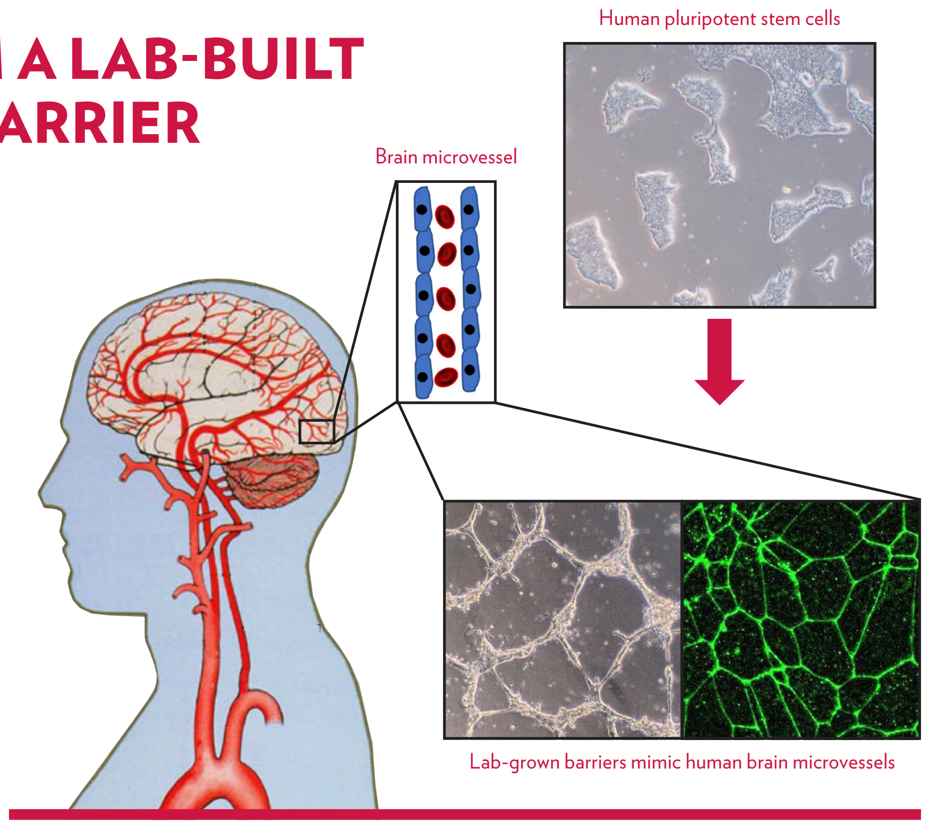
LEARNING FROM A LAB-BUILT BLOOD-BRAIN BARRIER

The blood-brain barrier is the brain's gatekeeper—keeping toxins and harmful invaders that may be in circulating blood from gaining access to the brain.

Unfortunately, in addition to protecting the brain, the barrier also is involved in disease and effectively blocks many of the small-molecule drugs that might make effective therapies for a host of neurological conditions, including such things as stroke, trauma, and cancer.

Rudimentary models of the barrier have been created in laboratories using human stem cells, but such systems haven't fully replicated the complex cellular behaviors observed in natural tissues.

In a report published November 8, 2017 in *Science Advances*, researchers detail a defined, step-by-step process to make a more exact mimic of the human blood-brain barrier in a laboratory dish.



Living tissue from the mysterious blood-brain barrier has long been impossible to study in the lab, but engineers have now devised a method to grow artificial blood-brain barriers using human stem cells.

> **The new method will allow industry to scale up production of the brain endothelial cells for drug discovery. By exposing cells to various agents, researchers can assess toxicity and effect of promising therapies.**

The new model will permit more robust exploration of the cells, their properties, and how scientists might circumvent the barrier for therapeutic purposes.

"The main advance is we now have a fully defined process that uses small molecules to guide cells through the developmental process," says Professor Sean Palecek.

To develop the new method, Palecek collaborated with colleague Professor Eric Shusta. Tongcheng Qian, a postdoctoral researcher, led the study.

By identifying specific chemical molecules that can chaperone cells through the various stages of development to become the blood-brain barrier, the Wisconsin team, in effect, provides a recipe that could be useful for things like high-throughput drug screens.

"It standardizes the approach. It can be applied to a broader portfolio of cells. We can really investigate disease," says Palecek, noting that an ability to track cells as they progress through various phases of development can help scientists see the cascade of cellular events that occur as neurological conditions manifest themselves.

The new method, he adds, will also allow industry to scale up production of the brain endothelial cells for drug discovery. By exposing cells to various agents, researchers can assess toxicity and effect of promising therapies.

The team has applied for a patent on the process through the Wisconsin Alumni Research Foundation, the not-for-profit organization that manages UW–Madison intellectual property.

IMPROVED CATALYSTS COULD HELP WIDESPREAD SOLAR POWER SEE THE LIGHT OF DAY

Engineers are shining a light on promising new strategies for storing solar power. The efforts could help overcome one major limitation of energy generation from solar sources—namely, how to keep up with electricity demand when the sun goes down.

"As renewable energy takes on a larger role in our power grid, storage and on-demand delivery are critical," says Professor Thatcher Root.

Renewable sources accounted for almost one quarter of the world's electricity generation in 2017, and solar power capacity has been growing at an annual rate of roughly 51 percent for the past decade. Unfortunately, consumer demand for electricity typically peaks in the evening, whereas solar energy generation is most efficient when the sun is high in the sky during midday.

That mismatch is why solar power plants need better systems to store solar energy—ideally something cost-effective and efficient. Integrating heat storage into the collection-generation system can be better than adding batteries or other separate storage systems.

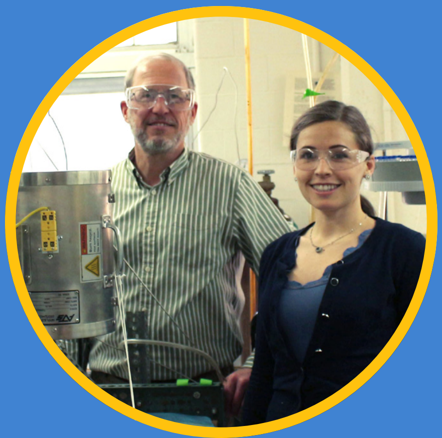
This approach can be especially useful for a renewable energy technology known as concentrating solar power (CSP), which is currently in use at almost 20 facilities in the United States. The plants collect heat from sunlight during the day and harness that energy to generate steam to power a turbine for electricity generation. With some care, the solar energy collected during the day can be stored as thermochemical energy—stored in chemical bonds—for nighttime use.

Root and graduate student Elise Gilcher, who is coadvised by James Dumesic, the Ernest Micek Distinguished Chair, are tackling the storage problem by developing better catalysts—materials that speed up chemical reactions without becoming consumed and transformed into new products.

The work will also be guided by Milton J. and A. Maude Shoemaker and Beckwith-Bascom Professor Thomas Keuch, who is world-renowned for contributions to catalysis research.

Some of the newest CSP plants use molten salt to store energy, but UW-Madison engineers have identified other methods. One promising option could be using a reversible methane reforming system, as described in a paper published April 13, 2017 in the journal *Green Chemistry*. Its authors include Xinyue Peng (a graduate student in Root's lab), Root, and Vilas Distinguished Achievement Professor and Paul A. Elfers Professor Christos Maravelias.

Methane thermochemical energy storage hinges on catalysts to assist the reactions used to store and release heat, and existing systems have one major problem. Over time, carbon builds up on the surfaces of catalysts (a process called "coking"), rendering them useless.



Professor Thatcher Root and graduate student Elise Gilcher are developing new catalysts that could make renewable energy generation more cost-effective and efficient. *Photo: Sam Million-Weaver*

"We need catalysts that don't coke up," says Root.

To tackle the problem, the team is working to chemically modify catalysts by applying a special anti-coking coating to the supported metal catalysts using a process called atomic layer deposition. The effort draws inspiration from earlier research spearheaded by Keuch and Dumesic, which showed that atomic layer deposition is suitable for catalysts in biofuels applications. Gilcher will modify the procedures for different catalysts that are more commonly used in methane reforming plants.

ALUMNA ACHIEVES SUCCESS IN BUSINESS

Even though Rebeccah Stay (BSChE '97) hasn't done a chemical experiment since she was an undergraduate, the alumna credits UW-Madison for launching her career.

"I always joke that the best thing I got out of studying engineering at UW-Madison was a lot of confidence," says Stay, who is the director of growth insights at Best Buy.

Stay's typical day involves working with statisticians and data scientists to determine optimum marketing and inventory strategies for the large retail chain. She learned business and strategy skills during her MBA coursework at Dartmouth, but her time at UW-Madison helped give her the all-important critical thinking abilities that allowed her to excel.

"The discipline to sit down and truly understand a technical problem opens up so many different careers," says Stay.

After completing her undergraduate degree, Stay initially planned to pursue an academic career and was accepted into the University of California at Berkeley chemical engineering PhD program. Two years later, however, an appealing job offer from Bain & Company lured Stay into management consulting. She left Berkeley with a master's degree in 1999.

During the data analytics boom of the late 2000s, Stay's training helped her adapt easily to a new software- and information-driven approach to making decisions.

"I'm very grateful for the world-class education I got," says Stay.

In particular, Stay cites the mentorship of former professor Juan de Pablo, who encouraged her to pursue graduate school. Other influential teachers were James Dumesic, the Ernest Micek Distinguished Chair, and Paul Nealy, who along with de Pablo is now at the University of Chicago.

Although the rigorous chemical engineering coursework kept Stay busy, she found time to play club ice hockey on the UW-Madison women's team for three years. Stay also studied abroad, spending her junior year in Dar en Salaam, Tanzania, which she describes as a phenomenal experience.

Stay recommends that current students also take full advantage of the different programs and extracurricular activities available on campus.

"UW-Madison is so rich with opportunities. Don't keep your head too far down," she says.

BABATUNDE OGUANNAIKE FOUND INSPIRATION AT UW-MADISON

Babatunde Oguannaike (PhDChE '81) grew up in a family of educators, so perhaps it's only natural that the alum earned multiple awards for excellence in teaching during his long and distinguished career.

Family wasn't his only influence, though. He fondly remembers learning from pioneering UW-Madison professors Bob Bird and Edwin Lightfoot during his formative years. In his current role as dean of the College of Engineering at the University of Delaware (a position he's held since 2013), Oguanaaike strives to emulate those educators both in the classroom and in his research endeavors.

"Good teachers teach well; great ones inspire. That's why the goal should be to inspire students, as my UW professors did me," says Oguanaaike.

Oguanaaike was so inspired by what he learned at UW-Madison that he went on to devote his career to process control research. Among the many honors he's received during his tenure as professor and dean at the University of Delaware, Oguanaaike is most proud of being elected into the National Academy of Engineering in 2012.

Currently, Oguanaaike focuses on applying control theory to biomedical problems for treating human disease. Such biological systems can be notoriously difficult to quantify; at the time of his dissertation defense in 1981, very few tools existed to accurately measure processes within the human body.

Several decades later, technology has improved, but fancy gadgets cannot cure disease on their own. Oguanaaike recognizes that engineers need to work across disciplines to improve people's lives.

"It's not enough to invent technology. To solve problems for humanity, it behooves us to understand for whom we are solving the problem," says Oguanaaike.

AT AGE 89, ARTHUR HAAG STICKS TO HIS GOALS

At the age of 89, Arthur Haag (BSChE '53) is still going strong and working full-time to run the company Neutrex Inc., which he founded more than 25 years ago.

Neutrex Inc. is one of seven companies that Haag helped found in the 65 years since he graduated from UW-Madison, and the alum has always had an outsized work ethic. Even as an undergraduate pursuing a demanding chemical engineering degree, Haag always worked several part-time jobs to pay for his schooling.

"I funded all but $100 of my education," Haag says, noting that his father floated him a small loan during one spring semester in 1951 when his resources became stretched perilously thin.

Among his many jobs, Haag worked as a waiter for his fraternity, Theta Chi, in exchange for room and board; he cooked at the snack bar between the Elizabeth Waters women's dorm and the adjacent men's dorm; and he translated documents into German for his advisor, Professor Roger Altpeter.

Haag spoke German at home as a child of immigrants; his parents came from Bavaria to Chicago in 1924. His father, a mechanical engineer, encouraged Haag to pursue chemistry.

"My father told me, Arthur, the future is in chemistry, physics, and math," says Haag.

He took those words to heart, enrolling at UW-Madison in 1947. He left Madison in 1951 for a two-year tour of duty in the U.S. Marine Corps during the Korean War. After completing his service, Haag finished the one remaining required course to receive his diploma in 1953.

Shortly after graduating, Haag contributed to a major breakthrough in the development of polypropylene (which is still widely used in textiles, plastic parts, and medical devices). While working for Stauffer in California, Haag helped design a unique high-temperature reactor for producing an essential titanium catalyst for converting the chemical building blocks of polypropylene into the useful material. That work led Haag to found his first company, ProChem, which produced a catalyst that is still widely used by the plastics industry.

Even though Haag is still working at the age of 89, he makes time to see several of his UW-Madison classmates as often as once a week. The alumni frequently get together to reminisce and play the card game Sheepshead. He's also an avid Badgers fan, and still follows the football team, occasionally attending games.

Haag has five children, 14 grandchildren, and three great-grandchildren. He gave his children the same advice that he imparts to aspiring chemical engineers, saying:

"Establish a goal in life, study it thoroughly before you adopt it, then stick by it tenaciously and carry it out."

That ethos motivates Oguanaaike to interact with scholars in the humanities, and he also engages in his own creative pursuits—including painting, writing, and playing guitar. He even once composed and recited a poem for an inauguration ceremony at the University of Delaware.

"It caught many people by surprise," he says. "They didn't expect the dean of engineering to write poetry."

The attendees could be forgiven for being unaware of Oguanaaike's ability to wax poetic, especially because engineers are likely more familiar with his hundreds of scholarly publications, including an influential textbook he coauthored with W. Harmon Ray.

Ray was an influential mentor and friend: "He taught me much more than chemical engineering," says Oguanaaike.

Every year, Ray hosted Thanksgiving dinner for international students, which is a tradition that Oguanaaike and his wife, Anna, continue to this day at their Delaware home.

Oguanaaike originally hails from Ibadan, Nigeria, which was a city of roughly 1.5 million people when he was growing up. He completed his undergraduate education at the University of Lagos in Nigeria. There, he studied under Ayodele Francis Ogunye, who was Ray's first PhD student. It was Ogunye who encouraged Oguanaaike to pursue graduate education at UW-Madison.

On a cold January day in 1978, Oguanaaike arrived in Madison, and immediately discovered that the coat he brought with him would be woefully insufficient for Wisconsin winters. He still remembers the thermometer reading that welcomed him to the Isthmus: a bone-chilling -21 degrees Fahrenheit.

He bought a down parka on the second day of spring semester.

After upgrading his wardrobe, Oguanaaike quickly adjusted to life on the Isthmus. The coursework was intellectually stimulating and he made several lifelong friendships. Summer evenings were often spent playing his guitar at the Memorial Union along with other musically inclined members of his cohort. It was on one of these evenings that Oguanaaike met his wife, Anna, who was a student in the music department at the time. They've been married since 1983.

Oguanaaike's passion for creative pursuits might seem atypical for an engineer, but he believes that cultivating wide-ranging interests better equips him to help solve the world's problems. He always advises students to work hard academically and to broaden their horizons.

"Never stop learning," Oguanaaike says. "Reach out to many people, including all types of engineers, but don't stop there. Read widely, go to concerts, and gain an appreciation of music and other forms of human creativity."

A LONG AND FULFILLING CAREER AT SHELL, THANKS TO UW-MADISON

After spending more than 35 years working for Shell Oil Co., Carlos Garcia (PhD '82) retired at the end of February 2018. Looking back, the alum credits his time in the department for kick-starting his long and distinguished career.

"I cannot talk about Shell without talking about UW-Madison," says Garcia.

Garcia came to campus in 1977 after earning his bachelor's degree in chemical engineering from the University of Puerto Rico. He decided to become a Badger based on the department's pioneering work in the field of catalysis. He also had encouragement from his undergraduate advisor, Professor Reynaldo Caban, one of the first engineers from Puerto Rico to earn a PhD from UW-Madison. Although Wisconsin was wildly different from Garcia's previous environs in sunny Puerto Rico, he quickly adjusted to life in Madison.

"I just fell in love with Madison immediately," says Garcia.

"It must have been divine intervention that inspired me to talk to Professor Morari, because that decision shaped my whole career," says Garcia.

Together, Morari and Garcia published influential papers describing the theoretical underpinnings of an important process control algorithm that was invented by engineers at Shell in the 1970s. One of those publications remains among the top-10 most-cited contributions in the process control field. The consulting work that Garcia did for Shell during graduate school paved the way for him to join the company immediately after completing his PhD.

"I could have stayed in academia," says Garcia. "But I knew that I didn't want to spend the rest of my life doing mathematical gymnastics. I wanted to see how the theories worked in the real world."

> "I wanted to see how the theories worked in the real world."

Garcia's first semester of graduate school was spent cramming for qualifying exams to earn him a coveted opportunity to enter directly into the chemical engineering PhD program without first obtaining a master's degree. He recalls hitting the books especially hard to make it through Professor Edwin Lightfoot's transport theory course. After passing his exams on a frigid Wisconsin winter day in early January, Garcia next needed to select his graduate advisor.

At a reception event for students to interview with prospective mentors, Garcia recalls large crowds of his colleagues jockeying for the chance to chat with Professors Bob Bird and Edwin Lightfoot. Instead of joining the throngs, Garcia initiated a conversation with a then-new professor, Manfred Morari, who had joined the faculty that same year.

In August of 1982, Garcia and his wife, whom he met at UW-Madison, relocated to Houston to begin working at Shell. They made the cross-country drive through scorching summer temperatures in a car without an air-conditioner—relying on a cooler full of ice in the backseat to prevent themselves from overheating.

Once in Houston, Garcia quickly got to work in research and development. During that time, research engineers at Shell had substantial autonomy to publish and he felt that the work had the best of both academic and industrial worlds. Garcia rapidly distinguished himself as a rising star and became a manager after six years.

Initially Garcia was hesitant to move away from a hands-on research role. "I was having too much fun," he says.

Yet he eventually realized that the opportunity to develop, mentor, and coach the next generation of process control engineers would allow him to have a more wide-ranging impact on the field.

Throughout the 80s and 90s, Garcia served in several capacities at Shell, including operations technology management at the Deer Park chemical plant and managing process and product technology developments at Shell Chemicals. Throughout his career, however, Garcia always maintained a fondness for process control—the focus of his dissertation research. So, he jumped at an opportunity to reconnect with his discipline in 2009 by taking a managerial position at Shell's Port Arthur Refinery. The process control engineering field had advanced since Garcia finished his PhD, but he quickly got back into the swing of things.

In 2012, Garcia was promoted to Global Discipline Head for process automation, control and optimization. In the role, he was responsible for developing the firm's engineering standards worldwide, with responsibility for more than 1,000 engineers from 32 countries across the globe. He was also accountable for advancing Shell's process control technology. In fact, several of the engineers on his team were involved in developing the fourth generation of the same algorithm that Garcia worked on during his time at UW-Madison.

"It was my dream job," he says.

Now in retirement, he no longer has to report to an office every morning—but the engineer plans to stay busy with consulting, writing, and part-time teaching.

"I not only have passion, but I want to give something back to the discipline," he says.

A CYLINDRICAL CROSSWORD PUZZLE BY BOB BIRD

INSTRUCTIONS:

Imagine that the grid above is wrapped tightly around a cylinder so that the leftmost column is exactly adjacent to the rightmost column. Thus you are working a crossword puzzle on the surface of a cylinder! Hence, to fill in the word fitting the definition for 10 Across, you would put O near the right edge and O and M near the left edge, on the same line to get the word for uncle in Dutch: oom.

The answer key is on the following page.

	1	2	3		4	5	6
7				8			
			9				10
		11				12	
	13		14		15		16
		17				18	
	19				20		
21				22			

Puzzle perpetrated by R.B. Bird

ACROSS:

1. Person honored on 11/11
4. Projection on a gear wheel
7. ___ and tonic
8. ___ drum
9. Frequently (in poetry)
10. Dutch for "uncle"
11. Wise bird
12. Capote's nickname
14. "Ich bin" in English
16. Weird
17. Pismire
18. Genetic molecule
19. Which was first, the chicken or the ___
20. Cow sound
21. Suffix for "verb"
22. Poem of praise

DOWN:

1. ___ and vigor
2. Type width
3. _-square
4. Let the ___ out of the bag
5. Companion of "either"
6. Gram (abbr.)
7. Type of Dutch cheese
8. Key of Bach's "St. Anne" fugue
9. Being in debt
10. Where U. of Maine is
11. Letter that is the same as a number
12. Type of intersection
13. Roman numeral for 500
15. Roman numeral for 1000
17. The stone ___
18. Female deer
19. Symbol for einsteinium
20. Symbol for mendelevium

ALUM NAMED FELLOW OF NATIONAL ACADEMY OF ENGINEERING

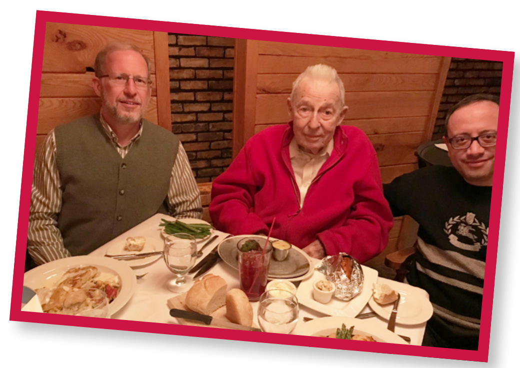
Raymond Gorte (BSChE '76) was elected a fellow of the National Academy of Engineering in February 2018 for fundamental contributions and their applications to heterogeneous catalysts and solid state electrochemical devices. Gorte received his PhD in chemical engineering at the University of Minnesota in 1981 and is currently the Russell Pearce and Elizabeth Crimian Heuer Professor of chemical and biomolecular engineering, and of materials science and engineering, at the University of Pennsylvania.

THANK YOU DONORS!

During the 20178-2018 academic year, 85 CBE undergraduates and 22 CBE graduate students received a grand total of roughly $239,000 in scholarships and $500,000 in fellowship funding. Many of those awards were enabled thanks to generous gifts from alumni and friends of the department.

Here, alum Mike (BSChE '73) and wife Mary Jensen (BsChE '74 from the University of Nebraska) *(both in red)* pose with Kiara Moyett, who received the Jeannie and Jinny Undergraduate Grant Scholarship for women pursuing careers in nursing and education, and Diana Mendez, who was awarded the Jensen Family Volleyball Scholarship Fund to provide scholarships to volleyball student athletes. Manos Mavrikakis is also pictured. Thank you, Mike and Mary, and to everyone who supports our students!

HAPPY BIRTHDAY, BOB!



Bob Bird recently celebrated his 94th birthday with faculty members Manos Mavrikakis and Thatcher Root. Bob is not only the department's resident puzzle master, he also is an active and frequent visitor to campus. We're especially grateful for Bob's ongoing efforts as historian to record memories from CBE's long and storied past.

Regina Murphy, the Smith-Bascom Professor, received the college Benjamin Smith Reynolds Award for Excellence in Teaching Engineers. Murphy has taught throughout the chemical engineering curriculum and, in many cases, she also worked to modernize the delivery of these courses. She has also devoted a decade and a half as associate chair of the chemical engineering undergraduate program, leads the undergraduate advising effort within her department, and has made significant contributions to undergraduate education at the college level.

Dan Klingenberg was selected to receive the Chancellor's Distinguished Teaching Award for his outstanding contributions to the educational mission of the department and the College of Engineering. Klingenberg has been a UW-Madison faculty member for about 25 years and has regularly taught CBE 320, a difficult core junior-level undergraduate class. In their nomination letter, his colleagues noted his unique ability to explain concepts and illustrate ideas in ways that help students grasp the material while still retaining the necessary rigor and mathematical complexity.

Ive Hermans received an H.I. Romnes Faculty Fellowship, awarded to faculty up to six years past their first promotion to tenured positions. Romnes Fellowships come with $60,000 to be spent over five years. Hermans, the John and Dorothy Vozza Professor in chemistry and a CBE affiliate, leads research to sustainably synthesize chemicals and fuels using catalysts.

Eric Shusta, the Howard Curler Distinguished Professor, received a new $300,000 catalyst award from the Falk Medical Research Trust to study an innovative form of immunotherapy for brain cancer. The approach targets target tumor regions with leaky blood vessels to recruit key immune system cells to attack and destroy the cancer.

George Huber (left) and James Dumesic (right) have consistently produced work that their peers have repeatedly judged to be of notable significance and utility.

Clarivate Analytics named **James Dumesic**, the Ernest Micek Distinguished Chair, and **George Huber**, Harvey D. Spangler Professor, to its 2017 list of highly cited researchers, which recognizes some of the most influential voices in science. Researchers named to this list have distinguished themselves by publishing a high number of papers that rank in the top 1-percent most-cited in their respective fields over an 11-year period.

Puzzle Answer Key

	1 V	2 E	3 T		4 C	5 O	6 G
7 G	I	N		8 E	A	R	
O	M		9 O	F	T		10 O
U		11 O	W	L		12 T	R
D	13 O		14 I	A	15 M		16 O
A		17 A	N	T		18 D	N
	19 E	G	G		20 M	O	O
21 I	S	E		22 O	D	E	

STUDENT NEWS

Kevin Barnett, a chemical and biological engineering graduate student, took second place in the Wisconsin Energy & Sustainability Challenge Global Stewards Sustainability Prize along with teammate Merve Ozen, an industrial and systems engineering graduate student. Their company, Pyran, has developed chemical reaction technology to produce 1,5-pentanediol from renewable wood and crop wastes, providing a low-cost and renewable means of creating a component of everyday paints and plastics.

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MEET AFFILIATE FACULTY MEMBER SAVERIO SPAGNOLIE

Saverio Spagnolie, an assistant professor of mathematics, identifies the mathematical laws that predict and govern how tiny lifeforms move through the world.

And Spagnolie, who has an affiliate appointment with the department, says a better understanding of these fundamental laws may unleash new and creative ideas for combatting harmful bacteria.

As an example, Spagnolie's models could reveal new approaches for preventing or treating the life-threatening condition called endocarditis where a persistent clump of bacteria adheres to the inner lining of the heart.

"When millions of bacteria form a matrix to solidify their stranglehold on the heart valve, this biofilm changes its mechanical properties, making it harder to pump blood into our body," Spagnolie says. "Treating endocarditis is exceptionally difficult, but if left untreated, the condition is almost always fatal."

A few years ago, Spagnolie developed a mathematical model that predicts which types of bacteria are attracted to surfaces by fluid mechanical forces alone, which may eventually help develop new drugs for bacterial infections, including endocarditis, dental caries, and other conditions associated with biofilms.

While Spagnolie focuses on the theoretical underpinnings of biolocomotion, the questions he tackles tend to start with biological experiments, many of which are relevant to human health. That's why he interacts closely with applied departments and enjoys co-advising graduate students and postdoctoral fellows in chemical and biological engineering with colleagues who have similar interests, including David Lynn, Nicholas Abbott, Daniel Klingenberg, and Michael Graham.

"Compared to my mathematics students, the engineering students have had more training in experimental work, so even if they don't do experiments themselves, they can relate to the realities of a physical problem, know what is more or less important, and are comfortable interacting with life scientists," Spagnolie says. "Working with both kinds of students is certainly one of the biggest benefits of my affiliate appointment with the department."