THE JOHNS HOPKINS WHITING SCHOOL OF ENGINEERING MAGAZINE

JHU ENGINEERING

SUMMER 2021

BARRIER BREAKERS

Johns Hopkins students with disabilities refuse to let their challenges define them.

FROM THE DEAN

Dear WSE community,

WHILE THE IMPACT OF COVID-19 IS NOT FULLY KNOWN AND EVEN AS SOCIETY CONTINUES TO ADDRESS ongoing challenges, I am thrilled to share with you that we're planning for a staged return of activity on the Homewood campus this fall.

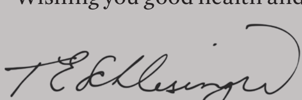
Our success with offering limited on-campus activities this spring was largely the result of our community members' compliance with the university's safety protocols and rigorous COVID-19 testing by the university. Now our intent is to offer a broad resumption of in-person classes for all students come September, while also providing remote learning options for students who are unable to attend in person, including international students who may face difficulties traveling to the United States.

Thanks to the dedication and hard work of our faculty and staff members, and the school's significant investment in technology, faculty training, and support, the quality of our academic programs has not waivered during the pandemic. Even so, it is undeniable that there are aspects of a student's campus experience that cannot be replicated online. The serendipitous encounter with a faculty member that sparks a student's research interests, a conversation over lunch that leads to a new business venture, or the lifelong friendships that form between roommates, teammates, and classmates all help fuel our students' academic and personal growth. We are committed to making these kinds of experiences possible, even as we take important steps to help ensure the health and safety of our community.

It is inevitable that as we "return to normal," we'll encounter some bumps and unanticipated challenges along the way, but I have seen firsthand how resilient and adaptable we are and am confident that we will be able to provide our students with the opportunities they want and deserve.

Over the course of my career, I can't remember seeing students and faculty members who are as eager and enthusiastic to start a new academic year as our current group. I look forward to sharing with you our experience as we come back to campus.

Wishing you good health and well-being,



ED SCHLESINGER
Benjamin T. Rome Dean

CONTRIBUTORS

WICK EISENBERG

MEET THE ENGINEER (P. 3)

Eisenberg is the communications specialist for the Department of Electrical and Computer Engineering at Johns Hopkins University, a position he has held since January 2019. Prior to coming to Johns Hopkins, he wrote a daily article for the official website of the Baltimore Ravens.

DAVID GLENN

GETTING THE DROP ON BETTER HEALTH (P. 17)

Glenn is an oncology nurse and freelance writer who contributes frequently to Johns Hopkins publications. He formerly served as a senior writer for *The Chronicle of Higher Education.* His articles have appeared in *Lingua Franca, The Nation,* and *The New York Times Book Review.*

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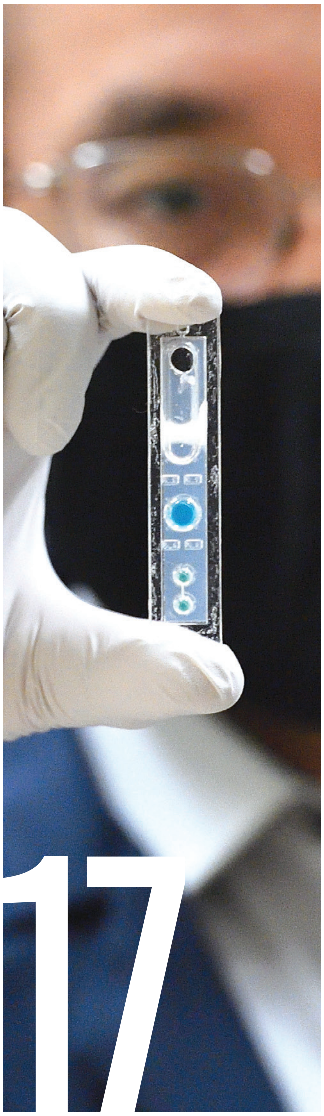
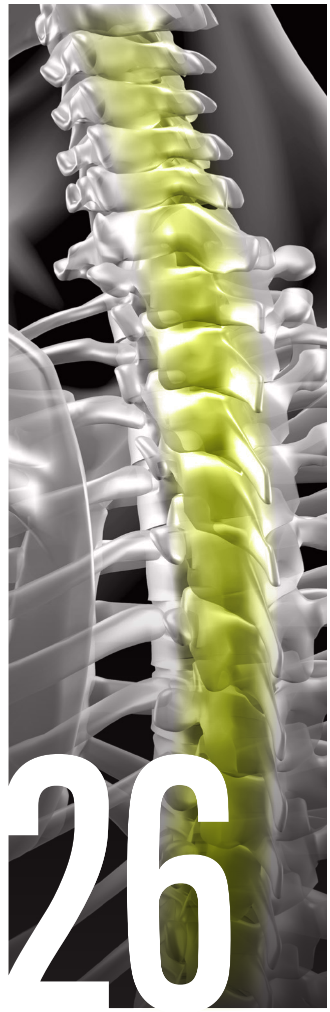




All COVID-19 safety precautions recommended by the Centers for Disease Control and Prevention were followed in the creation of content for this issue of *JHU Engineering* magazine.

A Catalyst for Sustainable Energy

LAUNCHED IN APRIL, THE RALPH S. O'CONNOR SUSTAINABLE ENERGY Institute, a university-wide initiative based at the Whiting School, is Johns Hopkins' new focal point for energy-related research and educational programs.

"The institute's activities focus on three overarching, connected themes: renewable energy, stewardship in fuel technologies, and affordable and equitable implementation," says Ben Schafer, the Willard and Lillian Hackerman Professor of Civil and Systems Engineering and the institute's founding director.

"Hopkins has never shied away from tackling enormous, complex societal problems—and this is one such challenge. With researchers from across the university collaborating and addressing these issues holistically, we can have a huge impact on advances in energy-related research, the nation's energy future, and in informing policy that ensures the benefits of our work will be enjoyed by all," Schafer says.

The broadest energy-related initiative ever at JHU, ROSEI will serve as a catalyst for activities focused on developing and translating sustainable energy technologies, educating future energy leaders, and helping create an affordable, scalable, and equitable green energy future for a more resilient world.

The institute was launched with a $20 million gift from the estate of trustee emeritus and alumnus Ralph S. O'Connor, support that is a catalyst for a new $75 million, 10-year total investment by the Whiting School and the university in energy-related research and education.

"This effort will be a game-changer in terms of advancing energy research and policy," says Ed Schlesinger, the Whiting School's Benjamin T. Rome Dean. "In addition, we'll realize other benefits as we continue attracting top faculty members and the most talented graduate students, expanding our academic offerings and student research opportunities, and providing targeted direct funding for energy-themed research."

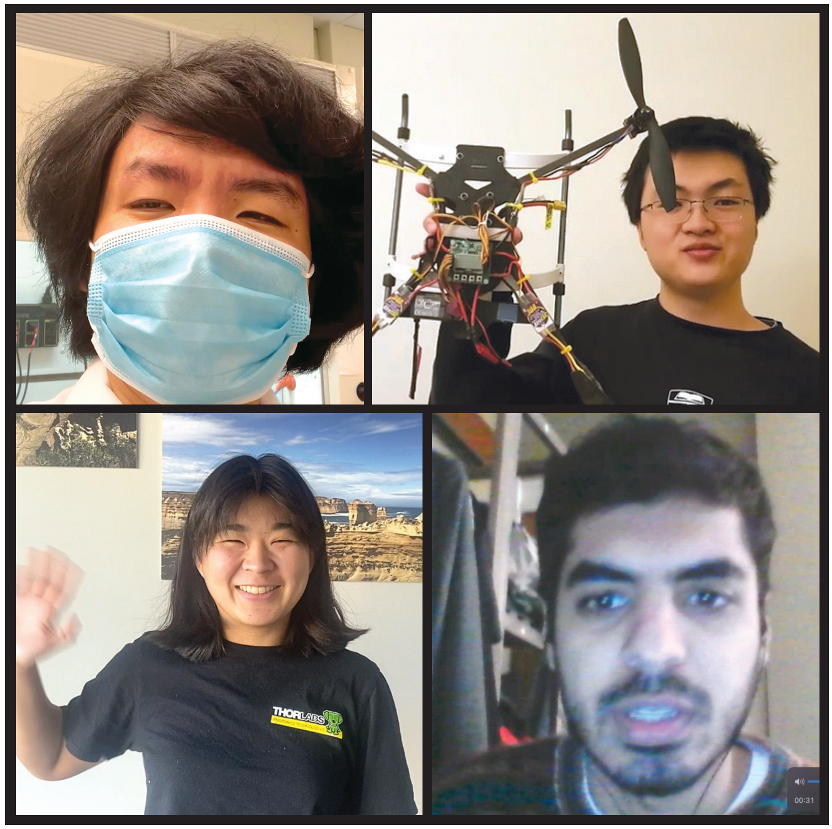
— ABBY LATTES

"This effort will be a game-changer in terms of advancing energy research and policy. In addition, we'll realize other benefits as we continue attracting top faculty members and the most talented graduate students, expanding our academic offerings and student research opportunities, and providing targeted direct funding for energy-themed research."

— ED SCHLESINGER, ***THE WHITING SCHOOL'S BENJAMIN T. ROME DEAN***

OPPOSITE PAGE: PHOTO CAPTURES COURTESY OF ERIC RONG, SREYAS CHINTAPALLI, AND ARLENE CHIU.

'Meet the Engineer'



JHU Engineering students created STEM-focused videos to inspire Baltimore City elementary schools students during remote learning.

SINCE LEARNING WENT ONLINE AS A RESULT OF THE GLOBAL PANDEMIC, KEEPING ELEMENTARY school students engaged while they attend school remotely has been an enormous challenge for teachers, parents, and students.

At the Whiting School, a group of electrical and computer engineering students combatted this problem by creating a series of short videos designed to stimulate Baltimore City Schools students' interest in studying science, technology, engineering, and math topics. In their "Meet the Engineer" series, the Johns Hopkins students talk about their own experiences studying engineering, their research, and what inspires and excites them about the field.

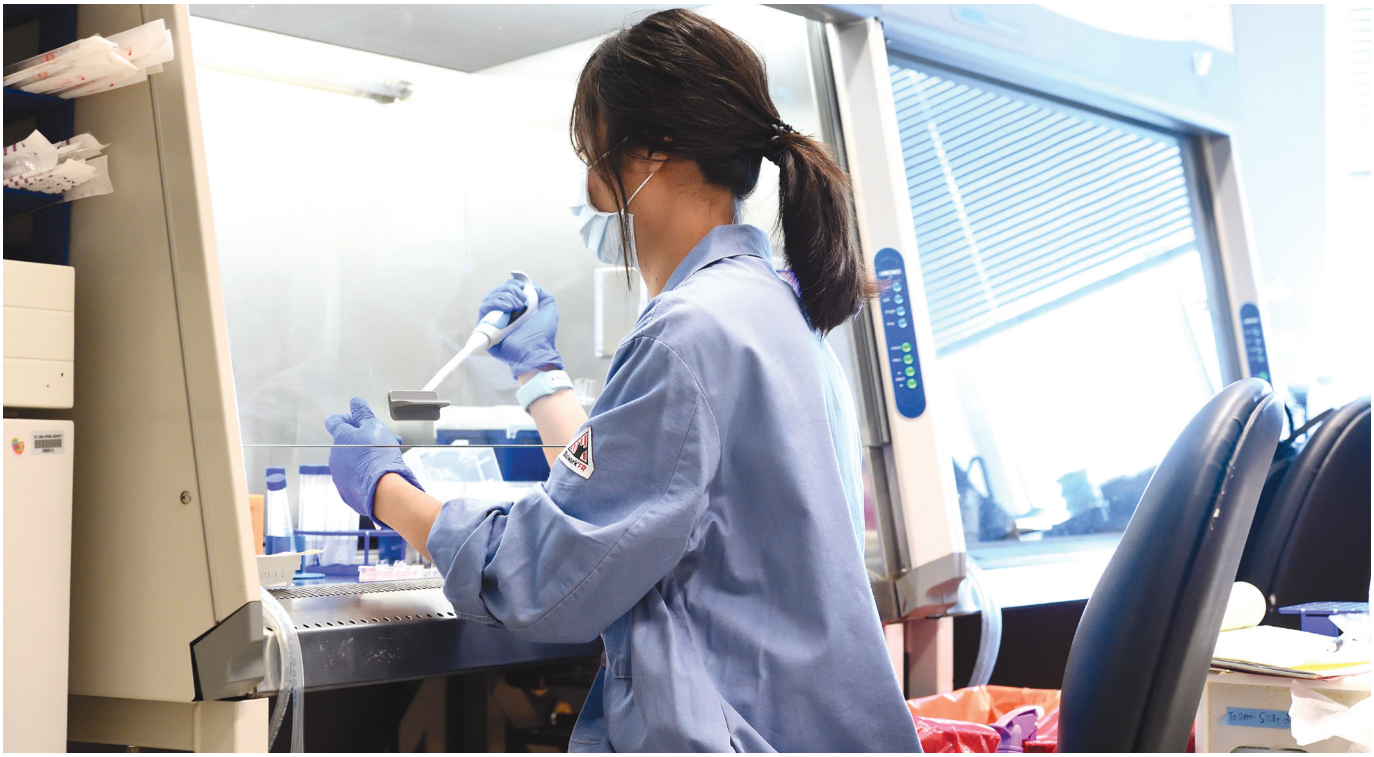
During non-pandemic times, these engineering students volunteer in the Whiting School's Center for Educational Outreach's STEM Achievement in Baltimore City Elementary Schools after-school program, focused on strengthening STEM skills in early grades.

SABES coach Stephanie Buggs came up with the idea for the videos. "We hoped the videos would provide students with an engaging experience and opportunity to connect with experts who would inspire their thinking about STEM," Buggs says.

Graduate student Arlene Chiu's video focused mainly on the process of designing experiments. "The main goal in creating these videos was to introduce myself to the kids, despite not being able to interact with them in person," Chiu says. Chiu's submission, in particular, created a buzz among the program's female students—not only because of the subject matter, but also because they were excited to see a woman engineer.

— **WICK EISENBERG**

> "We hoped the videos would provide students with an engaging experience and opportunity to connect with experts who would inspire their thinking about STEM."
>
> — **STEPHANIE BUGGS**



Sharon Gerecht's lab was among the first in WSE to receive My Green Lab certification, acknowledging its sustainability practices.

Certifying Sustainable Practices

GRADUATE RESEARCH ASSISTANT RYAN WEEKS WAS SHOCKED BY HOW much energy could be saved with only minor adjustments to lab procedures after he brought the My Green Lab sustainability certification program to the lab of Marc Ostermeier, professor of chemical and biomolecular engineering.

The My Green Lab certification process, now the global benchmark for measuring the environmental impact of laboratory practices, begins with all lab members completing a self-assessment of their practices in everything from plug load to waste reduction. After the responses are analyzed, My Green Lab provides a list of individually tailored recommendations for improving sustainable practices.

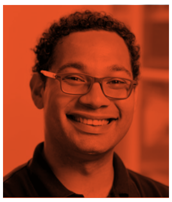
Christine Duke, lab coordinator for the Whiting School's Institute for NanoBioTechnology, came up with the idea to apply for certification for individual labs during the INBT's Green Office Certification renewal process. She asked INBT lab members if they wanted to participate, and Weeks signed on with the Ostermeier lab in Croft Hall, while Duke spearheaded the program in the lab of INBT Director Sharon Gerecht.

Per their recommendations, Ostermeier lab members began turning off and unplugging equipment at night, ordering from local suppliers, and fixing leaks in their vaults. Raising the specimen freezer's temperatures by just 10 degrees, to the still-safe -70 degrees Celsius, led to a 30% energy reduction, with each freezer saving a household's worth of energy every day.

Now Weeks, along with Duke and energy engineer Bena Zeng, want to bring the environmental certification process—and the sustainable changes it recommends—to the university as a whole.

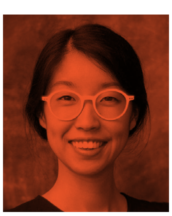
— JACOB DENOBEL

FACULTY AWARDS
NSF CAREER AWARD HONORS



ANTHONY SHOJI HALL, an assistant professor in the Department of Materials Science and Engineering, received the National Science Foundation's Early CAREER Award, which recognizes early-stage scholars with high levels of promise and excellence. Hall's award will support his project, "Room Temperature Electrochemical Synthesis of Ordered Intermetallic Nanomaterials," research aimed at designing high-performance ordered intermetallic nanomaterials for next-generation energy conversion devices.

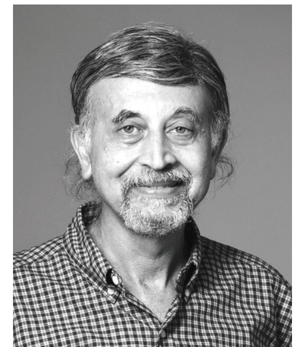
VISHAL PATEL, an assistant professor in the Department of Electrical and Computer Engineering, also received the NSF Early CAREER Award. Patel's award will support his team's project, "Seeing Through Atmospheric Turbulence: Image Restoration and Understanding Using Deep Convolutional Neural Networks." The algorithms they develop will be used to enhance the quality of images and videos collected by long-range and infrared imaging systems.



JEAN FAN, an assistant professor in the Department of Biomedical Engineering, received an NSF Early CAREER Award for her project, "Statistical Approaches and Computational Tools for Analyzing Spatially-Resolved Single-Cell Transcriptomics Data." Her work will provide insights into issues including cells' interactions in microenvironments and how spatial organization relates to cellular function and phenotype.

RAMALINGAM CHELLAPPA

SHARON GERECHT



NITISH THAKOR

Three Elected to National Academy of Inventors

Three members of the Whiting School's faculty were elected as fellows of the National Academy of Inventors, a distinction that recognizes and honors creators of outstanding inventions that have made a difference in society.

RAMALINGAM CHELLAPPA, a Bloomberg Distinguished Professor in the departments of Biomedical Engineering and of Electrical and Computer Engineering, and an expert in machine learning, was honored for work that has helped shape the field of facial recognition technology.

SHARON GERECHT, the Edward J. Schaefer Professor in the Department of Chemical and Biomolecular Engineering and director of the Institute for NanoBioTechnology, was honored for her expertise in vascular and stem cell biology and research aimed at engineering artificial cell environments.

NITISH THAKOR, a professor of biomedical engineering and a leader in neurological instrumentation, biomedical signal processing, micro and nanotechnologies, neural prosthesis, and neural and rehabilitation techniques, is developing a next-generation neurally controlled upper limb prosthesis.

COURSE CATALOG An intriguing spring offering:

RECYCLING FOR SUSTAINABILITY *(Materials Science and Engineering)*

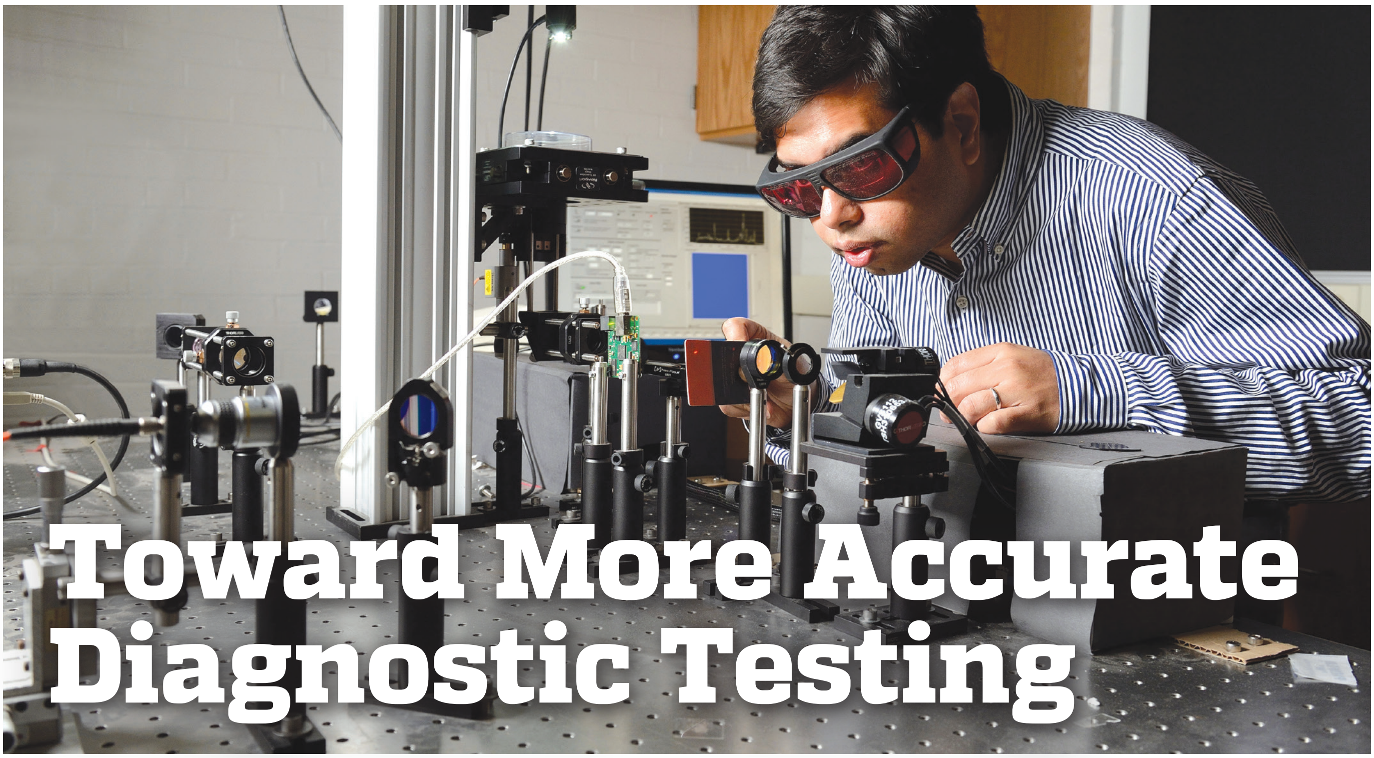
INSTRUCTOR: James Spicer

GUIDING QUESTION: "I'm so confused … which bin do I choose?"

COURSE FOCUS: Recycling's role in our strategies for material selection and product design for a sustainable future

SAMPLE TOPICS: The basics of recycling, from materials recovery, processing, and reuse to its economic and environmental impacts; industrial practices associated with recycling and how they relate to consumer behaviors.

15 The number of Johns Hopkins engineering students who received National Science Foundation Graduate Research Fellowships, recognizing outstanding work in science, technology, engineering, or math fields. Each student will receive more than $100,000 over three years in the form of a stipend and an allowance for tuition and fees. The funding is meant to provide students opportunities for international research and professional development, and the freedom to conduct their own research.



Toward More Accurate Diagnostic Testing

Ishan Barman

EVEN THE SMALLEST MOLECULE CAN TELL A BIG STORY. FOR INSTANCE, OBSERVING a single molecule can throw light on underlying biological processes in the human body. In fact, molecular imaging procedures—which are noninvasive and painless—are being used to diagnose and manage the treatment of COVID-19, cancer, heart disease, and other serious health conditions.

One of the more promising techniques for single-molecule imaging is surface-enhanced Raman spectroscopy, or SERS. By focusing a laser beam on the sample, SERS detects changes in molecules based upon how they scatter light and can identify specific molecules through their unique Raman spectra: a sort of molecular fingerprint. Advantages of SERS are that it is nondestructive and requires minimal sample preparation, as it does not require added chemicals or modifications to take measurements.

A Whiting School team led by Ishan Barman has described a novel nanomaterial that enables fast and highly sensitive single-molecule detection using SERS. The team's invention could pave the way for rapid and more accurate diagnostic testing. The scientists published their study recently in *Advanced Materials*.

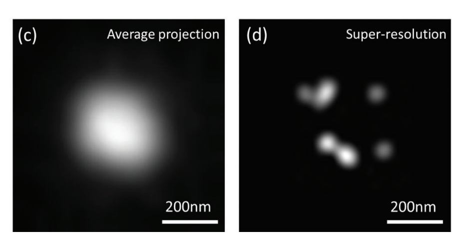
To create its new material, called DNA-Silicified Template for Raman Optical Beacon, or DNA-STROBE, the team engineered optical cavities of only a few nanometers or fewer. In SERS imaging, these plasmonic cavities "trap" beams of light by converting their electromagnetic radiation into electron waves. The Barman team's tiny plasmonic nanocavities exponentially increase the density of this trapped electromagnetic energy, potentially enabling quantitative biomolecular imaging at ultralow concentrations.

"The effectiveness of SERS measurements depends on the architecture and reproducibility of the nanoscale probes. If successfully designed and realized, our DNA-STROBE structures offer real-time, single-molecule, label-free optical sensing that is almost impossible to achieve with any existing platforms," says Barman, an associate professor of mechanical engineering.

The next step, the researchers say, will be to develop a set of tailored DNA-STROBE-derived analytical tools for a range of applications. For example, the team believes its approach offers a state-of-the-art platform for ultrasensitive detection of circulating cancer biomarkers.

"With suitable customization, the DNA-STROBE could enable progress in a wide variety of fields ranging from clinical diagnostics and basic biomedical research to environmental sensing and single-molecule manipulation," says Barman.

— CATHERINE GRAHAM



Images of the same plasmonic hotspot, created using diffraction-limited imaging (left) and the new DNA-STROBE (right), which enables the super-resolution needed to allow for single-molecule SERS.

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TELL US WHAT YOU THINK!

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"Mass ice loss from Greenland is the single largest contributor to sea level rise today, and Antarctica is projected to contribute significantly to sea level rise in the decades to come."

— HARIHAR RAJARAM

How Massive Glaciers Melt

NEW RESEARCH BY A TEAM THAT INCLUDED A JOHNS HOPKINS ENGINEER PROMISES TO ENABLE MORE accurate ice flow predictions, helping scientists better forecast how melting glaciers will contribute to rising sea levels, which have been linked to coastal and wetland flooding and destructive erosion around the world.

In a recent issue of *Journal of Geophysical Research: Earth Surface*, Harihar Rajaram and team offer a new method of estimating how heat flows upward from the Earth to beds of ice sheets in Greenland and Antarctica, affecting their viscosity and rates of movement.

"Mass ice loss from Greenland is the single largest contributor to sea level rise today, and Antarctica is projected to contribute significantly to sea level rise in the decades to come," says Rajaram, a professor of environmental health and engineering. "The temperature of ice near the bed determines how fast it can flow. It is important that ice sheet models incorporate accurate bed conditions so that we make correct projections out to 2050 and 2100. Our method is a big step in the right direction."

Rajaram worked on the study with experts from the Geological Survey of Denmark and Greenland, NASA, the University of Maryland, the University of California, and the University of Alaska.

The team's method is groundbreaking, Rajaram says, because it provides high-resolution estimates of variations in heat flow across a scale of hundreds of meters, accounting for the complex bed topography and geological features—such as valleys and ridges—underneath the massive ice sheets. Though it has long been understood that heat flow is greater in valleys and lesser on ridges, this was the first time a model has taken these factors into account.

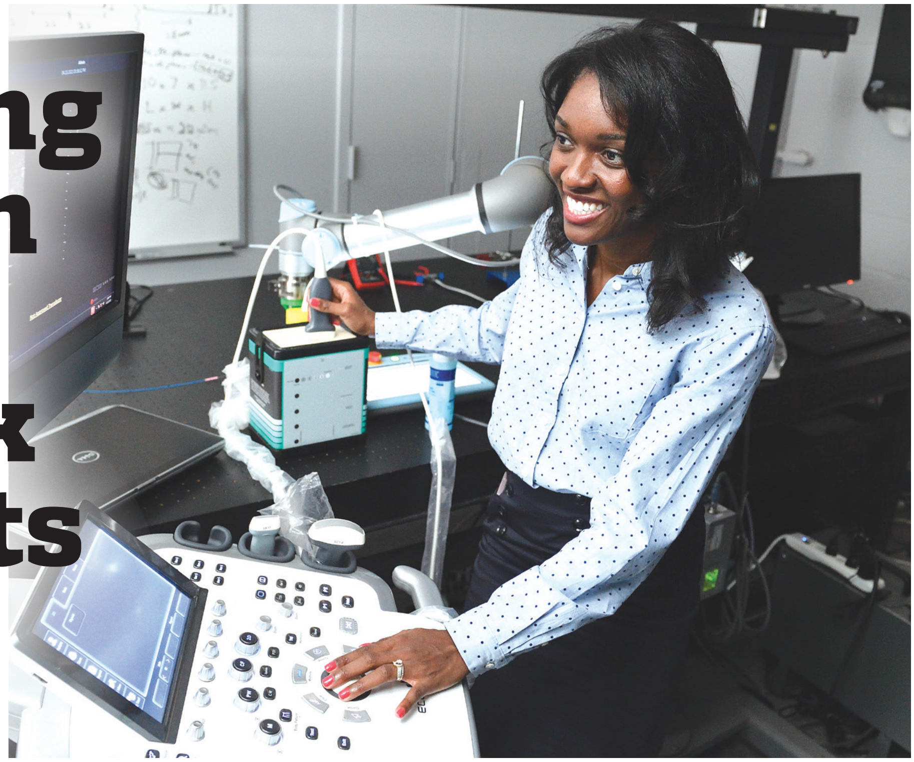
The researchers created a simple statistical model to estimate influence of glacier bed topography on geothermal heat flow and applied it to digital elevation models of the subglacial topography beneath the Greenland and Antarctic ice sheets. The result? A far more detailed geothermal heat flow map than what has been offered before.

"We discovered that heat flow in central East Greenland and the Antarctic Peninsula is halved along ridges and doubled within glacier valleys," Rajaram says.

The researchers hope their method and results will be not only adopted into present-day ice flow models to improve ice flow predictions but also used to estimate the influence of topography on geothermal heat flux in non-ice-covered areas.

— LISA DENIKE ERCOLANO

Achieving Equity in Funding for Black Scientists



Muyinatu Bell

INSUFFICIENT FEDERAL FUNDING FOR RESEARCH BY BLACK SCIENTISTS IS A key factor in preventing equitable contributions to science and achievement of these scientists' full potential, according to the Whiting School's Muyinatu Bell, the John C. Malone Assistant Professor of Electrical and Computer Engineering, who was among co-authors from 15 institutions whose commentary appeared in *Cell* in January.

"I pay taxes," says Bell. "My colleagues, friends, and family members who are all supportive of equity principles pay taxes. Yet there is a documented 20-year history of inequitable distribution of these tax dollars to Black researchers for biomedical research. This is a major problem that must be addressed."

In their commentary, Bell and her co-authors cite several studies of funding allocation by the National Institutes of Health to Black scientists over the past decade, which reveal that Black applicant award rates are about 55% that of white principal investigators of similar academic achievement. The authors contend that this funding gap has continued despite internal reviews of the reasons for the disparity and promises by NIH to do better.

The scientists point out that while efforts have been made to encourage Black students to enter careers as researchers and college and university faculty, once appointed, lack of research funding can stifle and even ruin their careers, especially as their ability to garner NIH and other funding plays into tenure and promotion decision-making.

"Differences in lab size, perceived research importance, and access to opportunities that require major NIH research funding are some of the consequences of the current disparity. Ultimately, these differences derail careers in a way that is not tied to aptitude nor fundamental potential for success," says Bell.

These disparities, Bell continues, can have far-reaching effects on future generations of scientists. "It's very important for young students to have role models in the sciences who come from the same racial background," she says. "These role models are effective with regard to changing perceptions about who is or who can be a scientist, not only for Black students but also for anyone watching the world around us."

She and her co-authors make several recommendations on how research funding disparities can be eliminated. Among the steps they recommend funding agencies take are:

- Explicitly state that racism persists in the U.S. research enterprise and that it must be expelled.
- Develop federal funding institute policies to immediately achieve racial funding equity.
- Incorporate diversity into research proposal scoring criteria, prioritize research teams that exemplify diversity, and diversify proposal review panel.
- Train funding agency leadership and staff, as well as grant reviewers and recipients, to recognize and stop racism.

Bell hopes that NIH will respond to the commentary by publicly acknowledging that

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“There is a documented 20-year history of inequitable distribution of tax dollars to Black researchers for biomedical research. This is a major problem that must be addressed.”

— MUYINATU BELL

there is a problem and by “implementing our suggestions to eliminate it, particularly with regard to insidious, double-standard comments at the grant review stage.”

The paper also urges individual scientists and universities to move beyond statements of solidarity to make meaningful and transformative organizational changes, and calls on those in the private sector—such as philanthropists and industrial leaders whose companies depend on scientific innovation, as well as on foundations and professional societies—to help offset racial disparities in research funding. Funding the innovative ideas and robust talents of Black scientists, the authors say, will benefit all of society.

“We all have the power to change this,” says Bell. “In doing so, it will help the entire biomedical research enterprise, as greater diversity in research at all levels has consistently translated to the delivery of more innovative science and technology.”

— **WICK EISENBERG**

3 Questions

Interview by Greg Rienzi

In waters spanning the west coast of North America all the way to Japan swirls the Great Pacific Garbage Patch, an 80,000-ton glob comprising more than 1.8 million pieces of plastic. The patch reflects not just humans’ voracious appetite for plastic packaging but also a failure to recycle. Only about 9% of plastic packaging is recycled; 12% is incinerated in facilities that create electricity or heat from garbage, and the remaining 79% ends up in landfills and the environment. A team led by **Chao Wang**, an associate professor of chemical and biomolecular engineering, has devised a way to transform the bulk of this worthless and harmful trash into something of value: p-xylene, a colorless chemical liquid used in manufacturing.

1 Can you walk us through the plastic treatment process?

In the lab, our group simulated the mixture that typically ends up in landfills by accumulating plastic and trash from home. We treat it with chlorine and then place it into a hydrocracking reactor. Then comes a two-stage process for hydrocracking depolymerization, a fancy name for plastic refining, akin to turning crude oil into gasoline. In step 1, the plastics react with a hydrogen catalyst to convert hydrocarbons to unrefined xylene. In step 2, pure p-xylene is separated from the less valuable isomers of xylene. P-xylene, worth $1 per kilogram, is a key building block in manufacturing things like rubber and leather products, and to refine other industrial chemicals.

2 How could this chemical process benefit the environment?

It provides an economic motivation to keep these plastics out of the water and land, with an added benefit of cleaning up the environment. The fact that companies want and need this product is what we hope will drive its commercialization. It could become a valuable commodity.

3 What next steps must happen in order to commercialize the process?

Within a year or two, we hope to demonstrate its effectiveness at a solid waste management facility in Maryland. If successful and implemented nationwide, the number of plastics recycled in the country could shoot up from 9% to 50%, or even higher. The sooner, the better.

A Towering Effort to Analyze Imperfection

Ben Schafer and doctoral student Victoria Ding determine the precise geometry of a thin-walled tube in preparation for structural testing.

WIND TURBINES PERCHED ATOP SLENDER STEEL TUBULAR TOWERS HAVE BECOME A COMMON sight as the nation's renewable energy infrastructure rapidly expands.

These supporting towers are a remarkable feat of engineering. While the lightweight design of these thin-walled tubes can make them extremely efficient in terms both of generating energy and their cost, imperfections that occur during the manufacturing process can leave them vulnerable to premature failure, a challenge that can result in manufacturers increasing the materials needed for construction.

Now, supported by a grant from the National Science Foundation, an engineering team is studying the link between the tower manufacturing processes and the structural behavior of these remarkable tubes. The team is co-led by the Whiting School's Benjamin W. Schafer, director of the Ralph S. O'Connor Sustainable Energy Institute; Michael Shields, an expert in uncertainty quantification and an associate professor of civil and systems engineering; and Northeastern University Professor Andrew Myers, BS '04, an expert in wind turbine towers.

"The fact that we don't understand the nature of this relationship is a barrier to exploiting the true efficiency of these elements. Every bit of unnecessary steel we add into the towers takes away from our overall goals for a sustainable energy future," says Schafer, the Willard and Lillian Hackerman Chair in the Department of Civil and Systems Engineering.

The grant is part of the NSF's Grant Opportunities for Academic Liaison with Industry program and involves a collaborative study with the wind energy company Vestas. The study is a first of its kind, as it involves collaboration with Vestas experts and access to their Colorado wind turbine factory.

Access to the factory and its manufacturing process will help the team overcome one of the biggest impediments to understanding thin-walled tubular structures: The tubular elements used in civil infrastructure and mechanical systems are too large to be prototyped, iteratively designed, and tested at full scale. Because of this, in the past, designers have had to estimate the elements' structural strength, including the critical imperfections that can occur during manufacturing. The collaboration with Vestas now will enable the research team to move beyond estimation to directly measure full-scale segments of the towers and develop precise information of the actual process.

"The ability of today's noncontact measurement tools, [together] with access to directly measure tower geometric imperfections, means we can develop a sizeable database of measured imperfections," says Schafer. "Combined with current simulation tools, this is exactly what engineers will need to reliably predict the strength of these towers as we push forward."

— LDE

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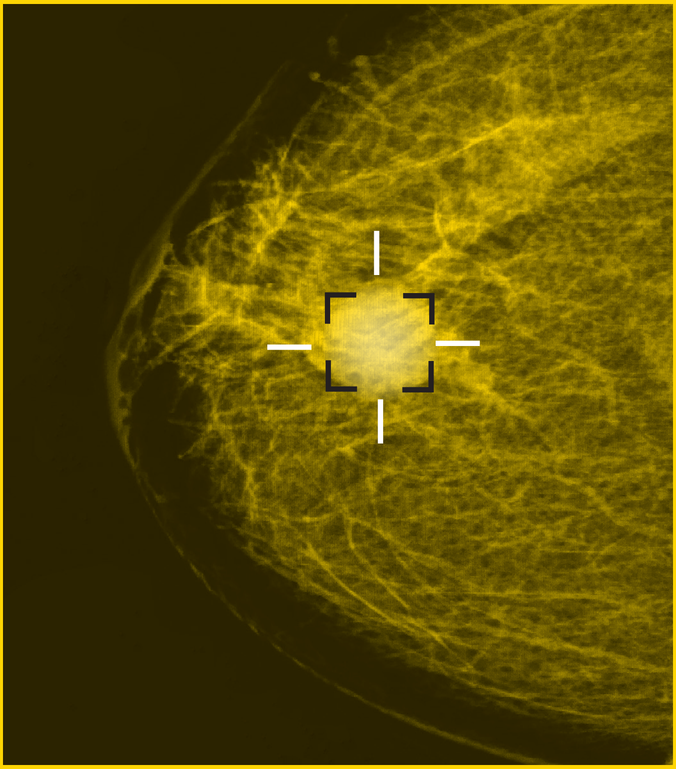

1 A BETTER TOOL FOR TREATING SOLID TUMORS

When cancer spreads, it dramatically decreases survival rates. If physicians could predict the likelihood that primary tumors will metastasize, they would be able to choose the best treatment options, but current testing only reviews tumor genetics, which can mutate and change.

Konstantinos Konstantopoulos and a team of researchers are creating a diagnostic tool and method for predicting breast cancer metastasis by looking instead at the tumor cell phenotype.

Called the Microfluidic Assay for Quantification of Cell Invasion, or MAqCI, the tool identifies aggressive breast cancer cells based on their ability to move and squeeze from a feeder channel into narrower channels, as well as their capacity to proliferate. These are two key cell behaviors needed for metastasis.

"MAqCI has the potential to diagnose a tumor's metastatic propensity and screen therapeutics that target metastasis-initiating cells on a patient-specific basis for personalized medicine," says Konstantopoulos, the William H. Schwarz Professor of Chemical and Biomolecular Engineering and core member of the Institute for NanoBioTechnology.

"We have also carried out pilot retrospective and prospective studies showing that MAqCI has potential to accurately predict survival expectancy of brain cancer patients. We believe that MAqCI will be a great tool for diagnosis, prognosis, and precision care of patients with solid tumors." The technology will be developed with support from a Maryland Innovation Initiative award.

— GINA WADAS

2 COVID-HEART PREDICTOR

Using data from 2,178 patients treated at five hospitals in the Johns Hopkins Health System between March 1 and Sept. 27, 2020, a team of Johns Hopkins University biomedical engineers and Johns Hopkins Medicine heart specialists have developed an algorithm that warns doctors several hours before hospitalized COVID-19 patients experience cardiac arrest or blood clots.

The COVID-HEART predictor can forecast cardiac arrest in COVID-19 patients with a median early warning time of 18 hours and predict blood clots three days in advance.

"It's an early warning system to predict in real time these two outcomes in hospitalized COVID-19 patients. The continuously updating predictor can help hospitals allocate the appropriate resources and proper interventions to attain the best outcomes for patients," says senior author Natalia Trayanova, a professor of biomedical engineering and a professor of medicine. Her lab was awarded one of the first grants from the National Science Foundation's Rapid Response Research effort for this work earlier in the pandemic.

The next step for the researchers is to develop the best method for setting up the technology in hospitals to aid with the care of COVID-19 patients. The team is in talks with a company interested in commercializing the technology.

— DOUG DONOVAN

3 LESS-POLLUTING CARGO SHIPS

An integral part of our global economy, maritime shipping accounts for almost 3% of global carbon dioxide emissions, and experts at the International Maritime Organization expect that percentage to rise 50% to 250% by 2050 if no action is taken.

A team of Johns Hopkins mechanical engineers has put a new spin on an old idea: Make modern cargo ships more efficient—and less polluting—by adding a new mechanism to a rotor that is increasingly in use as a cleaner propulsion system.

"We have added a mechanism to the Flettner rotor that imparts localized suction to it," says Rajat Mittal, a professor of mechanical engineering. "Our design enhancement leads to an increase of 80% to 180% in rotor thrust, and an increased efficiency that translates to significant reduction in carbon dioxide emissions."

The team, which also includes mechanical engineers Rui Ni and Jung-Hee Seo, has validated its design through computer models and simulations, and is working with Johns Hopkins Technology Ventures to commercialize it.

"If the shipping industry was a country, it would rank sixth in the world carbon dioxide emissions league table," Mittal says. "Even a small increase in the efficiency of a ship propulsion, such as via our invention, could have a significant impact on pollution and global warming."

— LDE

Testing for Bacteria

THE COVID-19 PANDEMIC HAS MADE CLEAR THE THREAT THAT SOME viruses pose to humans. But viruses can infect bacteria too, impeding their vital role in sustaining life on our planet. Sick bacteria are stymied in their function as decomposers and as part of the foundation of the food web in the Chesapeake Bay and other waterways, although infections of bacteria can also be beneficial in stopping harmful algal blooms or preventing greenhouse gas production.

But how can you tell if a bacterial population is sick? To find out, a team led by environmental engineer Sarah Preheim has developed an effective and affordable test that's similar to the polymerase chain reaction test used to test humans for COVID-19.

"If there was a COVID-like pandemic occurring in important bacterial populations, it would be difficult to tell, because before this study, we lacked the affordable and accurate tools necessary to study viral infections in uncultured bacterial populations," says Preheim, assistant professor of environmental health and engineering, whose team reported its work recently in *Nature Microbiology*.

Determining viral infections in bacteria traditionally relies on culturing both bacteria and viruses, which misses 99% of bacteria found in the environment because they cannot be grown in culture, Preheim says. She notes that tests of viral infections in uncultured bacteria are expensive and difficult to apply widely, not unlike the early stages of COVID-19 testing.

The key to making a test of viral infections for uncultured bacteria faster and more affordable is being able to isolate single bacterial cells in a small bubble (i.e., an emulsion droplet) and fuse the genes of the virus and bacteria once the bubble.

"The fused genes act like nametags for the bacteria and viruses," says the study's lead author, Eric Sakowski, a former postdoctoral researcher in Preheim's laboratory who is now an assistant professor at Mount St. Mary's University. "By fusing the genes together, we are able to identify which bacteria are infected, as well as the variant of the virus that is causing the infection."

The resulting test provides a novel way to screen for viral infections in a subset of bacterial populations. The test allows researchers to identify a link between environmental conditions and infections in Actinobacteria, one of the most abundant bacterial groups in the Chesapeake Bay and one that plays a crucial role in decomposing organic matter and making nutrients available to plants and photosynthetic algae.

Though the researchers developed this tool studying the Chesapeake Bay, they say their approach could be widely applied across aquatic ecosystems, shedding light on viral ecology and helping predict—and even prevent—devastating environmental impacts.

What's more, the new test could someday also affect how we treat bacterial infections, says Sakowski. "Viruses show potential for treating infections caused by antibiotic-resistant bacteria," he says. "Knowing which viruses most effectively infect bacteria will be critical to this type of treatment."

— LDE

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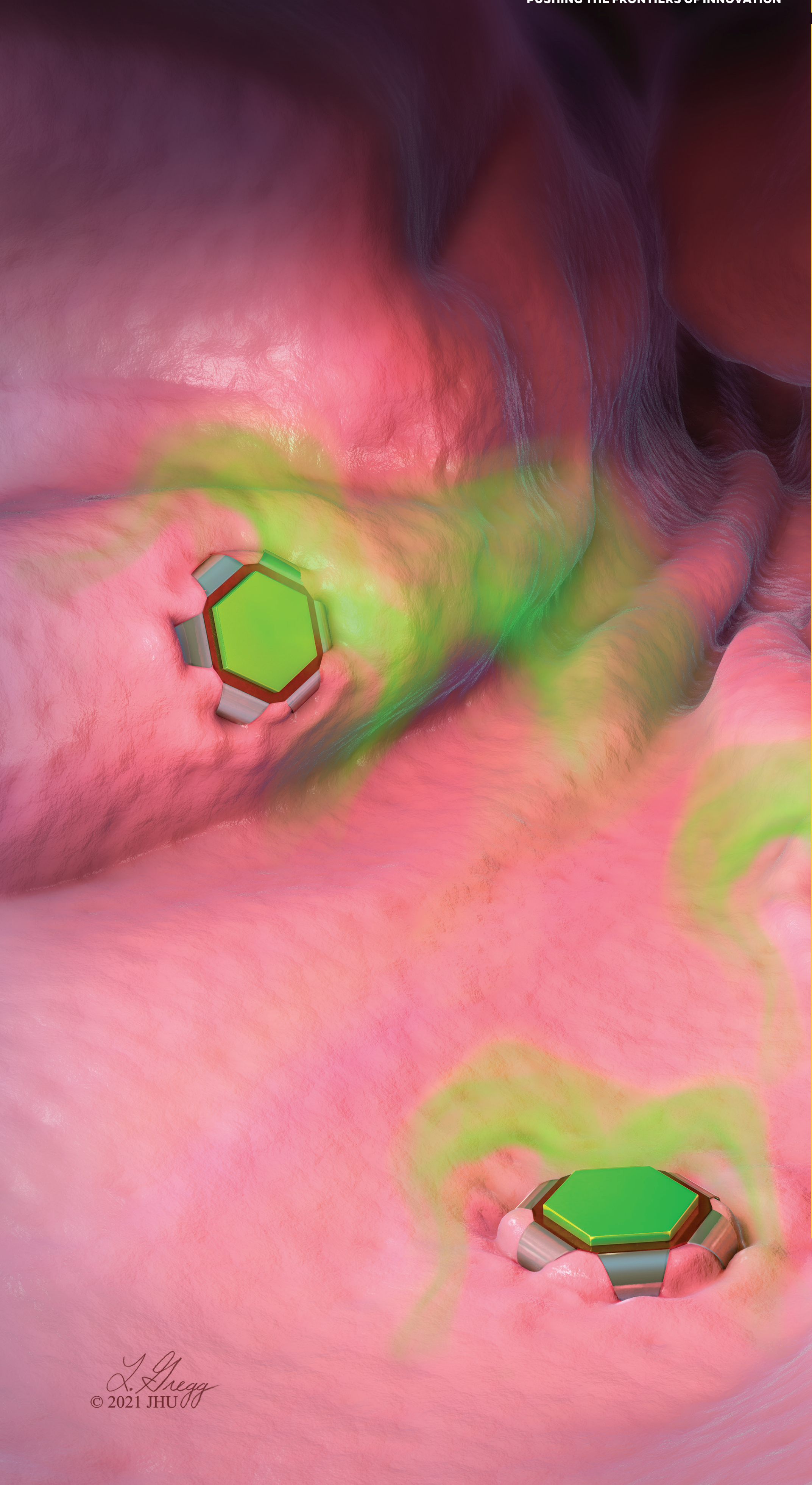
TECH TOOLS



Get a Grip!

Inspired by a parasitic worm that digs its sharp teeth into its a host's intestines, Johns Hopkins researchers have designed tiny, star-shaped microdevices that can latch onto intestinal mucosa and release drugs into the body.

Whiting School professor David Gracias and gastroenterologist Florin M. Selaru, director of the Johns Hopkins Inflammatory Bowel Disease Center, led a team that designed and tested shape-changing microdevices that mimic the way the parasitic hookworm affixes itself to an organism's intestines.

The therapeutic grippers (or "thera-grippers") are self-latching devices made of metal and a thin, residually stressed shape-changing film, then coated in heat-sensitive paraffin wax. The devices, each roughly the size of a dust speck, can potentially carry any drug and release it gradually into the body. When the paraffin wax coating on the grippers warms up inside the body, the miniscule devices close autonomously, clamping onto and digging into the mucosal colon wall, releasing their medicine payloads gradually. Eventually, they relax their grips and are cleared from the intestine via normal gastrointestinal muscular function.

"Our results provided the first in vivo evidence that shape -changing microdevices can enhance the efficacy of extended drug delivery and represent a new paradigm for smart therapeutics," Gracias says.

— PATRICK SMITH

"I used to worry about brainstorming sessions where all the white guys were over here, and I was over here. But guess where the solution was—somewhere in between."

2/23/21, *NPR*
James West, Department of Electrical and Computer Engineering, on invention and inclusion in science.

"To say there was no impact to air quality was crazy."

12/1/20, *REUTERS*
Peter DeCarlo, Department of Environmental Health and Engineering, on how U.S. air monitors routinely fail to detect pollution—even from major toxic releases, including one generated by the refinery explosion in Philadelphia in 2019.

"We were thinking, well, how does nature solve this problem? And we knew that there are worms and other organisms that colonize and live in the gastrointestinal tract for a long period."

11/18/20, *BBC SCIENCE FOCUS*
David Gracias, Department of Chemical and Biomolecular Engineering, on using parasitic worms as a model for tiny microgrippers that deliver drugs inside patient's bodies (read more on p. 13).

"There's a whole black market of people out there who are finding vulnerabilities and building exploits and often selling them to the highest bidder."

11/6/20, *WBAL-TV11 STORY*
Avi Rubin, technical director at the Johns Hopkins University Information Security Institute, on a ransomware attack that crippled the Baltimore County Public Schools system last fall.

GETTING THE DROP ON BETTER HEALTH

THROUGH HIS MANY ADVANCES IN MICROFLUIDICS, JEFF WANG IS MAKING IT QUICKER, EASIER, AND CHEAPER FOR CLINICIANS TO IDENTIFY INFECTIOUS PATHOGENS AND DIAGNOSE DISEASES EARLIER.

Written by: **DAVID GLENN** / Photographs by: **WILL KIRK**

Professor of mechanical engineering Tza-Huei (Jeff) Wang spends his days working with tiny droplets of fluid. Some of his lab's devices analyze droplets that are one-millionth of a liter. Others use a far smaller scale: one-trillionth of a liter.

Why would anyone want to isolate such minute volumes of fluid? Because microfluidics, as Wang's field is known, allows rapid, precise analysis of many kinds of biological processes.

Over the last decade, Wang's lab has developed devices that might someday make it far easier for clinicians to identify infectious pathogens and to diagnose early-stage cancers. And because some of these devices have the potential to be cheap and portable, they might transform health care in low-resource countries that have few traditional hospital laboratories.

"With microfluidics," Wang says, "you can control the microenvironments you want to look at. You have precise temporal and spatial control. You have resolution even down to the single-cell level. It's a very elegant approach."

To translate his lab's technologies into real-world clinical progress, Wang has built collaborations with a broad team of physicians and epidemiologists at Johns Hopkins and elsewhere.

One of Wang's highest-profile recent projects involves a portable device that can rapidly confirm an infection with gonorrhea—and, remarkably, can identify within 15 minutes whether the gonorrhea will respond to traditional antibiotics. In a typical hospital lab, that process takes two to four days. But with Wang's device, a patient can receive a diagnosis and start treatment, all within a 45-minute clinical visit.

"It's a huge benefit to start treating the patient during that initial visit," says Charlotte Gaydos, a professor of infectious diseases at the Johns Hopkins University School of Medicine,

"With microfluidics, you can control the microenvironments you want to look at. You have precise temporal and spatial control. You have resolution even down to the single-cell level. It's a very elegant approach."

– TZA-HUEI (JEFF) WANG

who has collaborated with Wang for more than seven years. "Usually, you're waiting several days for results to come back, and during that time, there's a risk of further transmission of infection."

Wang, Gaydos, and their colleagues have tested their device in the Emergency Department at the Johns Hopkins Hospital and at several clinics in Baltimore. They have also piloted the system in rural areas of Uganda, where antibiotic-resistant gonorrhea is becoming prevalent.

At each site, Wang has worked to make sure that the device actually fits into the local clinical workflow. "Ten years ago," he says, "some people were very, very frustrated with microfluidics because we'd invented all of these very elegant, very powerful microchips, but they couldn't be used easily in clinical settings. People didn't see a lot of actual real-world products."

To avoid that pitfall, Wang teaches his graduate students and postdocs to have long, deep conversations with their physician collaborators. "Don't just read their papers," he says. "Go and visit their clinics and see how the work actually happens."

Using that collaborative approach, Wang's lab has developed an array of devices for detecting cancer and analyzing pathogens. With Stephen Meltzer, a professor of oncology at Johns Hopkins, Wang has developed a new technique for detecting precancerous changes in the esophagus. With Karen Carroll, a professor of pathology, he has developed a microfluidic platform that can accurately identify any of dozens of pathogens in a tiny specimen of urine. Like the gonorrhea device, this platform can deliver extremely fast reports about the pathogens' sensitivity to antibiotics.

PUSHING THE LIMITS

Wang was raised in Taiwan, and he earned his bachelor's and master's degrees there. He worked for two years in the mid-1990s at a major Taiwanese semiconductor firm, where he found himself becoming a bit bored. "As an entry-level engineer," he says, "the scope of your work was quite limited."

He started to hear about the emerging field of microelectromechanical systems—the science of developing small sensors combined with tiny mechanical elements. (Think of the proprioceptive sensors that tell your cellphone which way is up.) In 1998, he successfully applied to the doctoral program at UCLA, which was a pioneering center of MEMS research.

"The UCLA program was very exciting," he says. "At that time, not many people were interested in applying MEMS techniques to biomedical problems. But there were a handful of us there who wanted to make it happen."

An early project at UCLA involved a Defense Department grant for developing small devices that could detect anthrax or other biowarfare agents. "My challenge was to try to push these devices to the fundamental limit," Wang says. "We wanted to see whether you could transduce DNA-binding events to an optical signal detectible at the single-molecule level." It was this project, Wang says, that provided the

A microfluidic device Wang created for multiplex COVID-19 testing that can differentiate SARS-CoV-2 variants and other respiratory viruses.

proof of concept for all of his subsequent work in microfluidics.

Wang arrived at Johns Hopkins as a junior faculty member in 2002. He was hired directly from UCLA, without having completed a postdoctoral fellowship. "I was quite stressed at the beginning," he says, "because I didn't have much teaching experience. I didn't have experience writing grants. I knew that the tenure clock would start ticking as soon as I set foot on campus. But I had great support from senior faculty, and it all worked out well."

Gaydos, Wang's collaborator on the gonorrhea device, says she appreciates his flexibility and his willingness to reach across disciplines. "When I first started to work on point-of-care devices for sexually transmitted infections," she says, "Jeff approached me and said he had technology for cancer diagnosis—detecting single-nucleotide polymorphisms—that we might be able to apply to identifying antibiotic susceptibility. He dove right into the problem."

Wang says that his visits to the Ugandan clinical sites in 2019 were among the most valuable experiences of his time at Johns Hopkins. "While I was there," he says, "I heard about a problem I'd never even thought about. Clinics in Uganda sometimes get shipments of counterfeit antibiotics, and they can't tell what's real. So that might be my next project: a portable device for the rapid authentication of medicines."

The new generation of doctoral students in engineering, Wang says, tends to be highly committed to that kind of practical, translational work. "I don't mean that basic science isn't exciting," he says. "It's very exciting. But the students I see today also want to make an impact in the real world."

Wang and his colleagues are preparing to have a few of their pathogen-detecting devices cleared for use by the FDA. Before long, his lab's work with tiny droplets could have an enormous impact. ▪

BARRIER BREAKERS

Like hundreds of students at Johns Hopkins who contend with disabilities, Isaac Diaz refuses to be defined by his challenges. Find out what steps the university is taking to help him and others flourish.

By JOAN KATHERINE CRAMER
Photos by WILL KIRK

Catherine Axe, executive director of JHU Student Disability Services

Terri Massie-Burrell, director of Student Disability Services on the Homewood campus

Issac Diaz, chemical and biomolecular engineering major

What is a disability? For Isaac Diaz, a second-year chemical and biomolecular engineering major from North Carolina, it is a mysterious illness that developed suddenly when he was 11, leaving him paralyzed. For Maryland native Fatima Ceesay '21, also majoring in chemical and biomolecular engineering, it is an anxiety disorder that only became apparent and started seriously interfering with her work after she came to Johns Hopkins.

There is great diversity when it comes to conditions, from autism to mood disorders, from dyslexia to missing limbs, that can interfere with the ability to fully participate in university life. But different as their needs might be, both Diaz and Ceesay are ambitious students who refuse to be defined by their challenges. And they say the accommodations and philosophy of inclusion provided by Student Disability Services, on the Homewood campus and university-wide, have helped make it possible for them to thrive.

Their guide through the process is Terri Massie-Burrell, who heads disability services at Homewood and is currently serving the needs of some 700 students. Massie-Burrell acknowledges that the number of students with disabilities who would likely be eligible for services is probably far greater, but says that many fear being identified as disabled.

"Our goal is to change the way disability is seen—not as an impairment, but as part of a student's unique identity, just like race and gender and class and all of the other differences that contribute to the richness of the culture," she says. "Also, it's only

part of a student's identity and only part of their experience. You can have two students with the same disability, for instance, with very different needs."

Massie-Burrell says many barriers aren't immediately obvious and often relate to other aspects of identity, like socioeconomic status or race.

"To do our jobs well, we have to understand and serve the whole student. Suppose you are the first person in your family to go to college. What are the financial and social pressures you are experiencing?" she says. "What if you are deaf and a police officer asks you to stop, and it appears you ignore him because you didn't hear him? What if you are a tall African American male with autism in an encounter with the police?"

Massie-Burrell has had her own experience with barriers. She was born without one of her hands and uses a prosthesis. "I often come to a door carrying a package and have to use that handicap button," she says. "It's amazing how many things require two hands."

She says her job is intense, detail-oriented, and endlessly creative. The Centers for Disease Control and Prevention estimates that one in four adults has a disability, and anyone can develop a disability of some kind at any time. And though Massie-Burrell's office also serves as a resource for faculty and staff members who are looking for ways to better serve students, she says the best way to find out what students with disabilities need is to ask them.

"One of the slogans of the disability community is 'Nothing about us without us,'" she says. "We have some very, very bright students here who want to be as involved as possible in making certain we are providing appropriate services."

Not 'Less Than'

For Ceesay, it took a while to come to terms with the fact that something was wrong. "Things that were easy for me in high school were suddenly very difficult," she says. "I was struggling with my course work, having trouble focusing, and developed really bad test anxiety, both leading up to the test and in the exam room. I would actually get chills and shortness of breath. I was having anxiety attacks without even knowing what they were."

Reluctant to acknowledge what she was afraid would be the stigma of a disability, Ceesay tried other support services the university provides, including working with tutors and even a study consultant to help her manage her time.

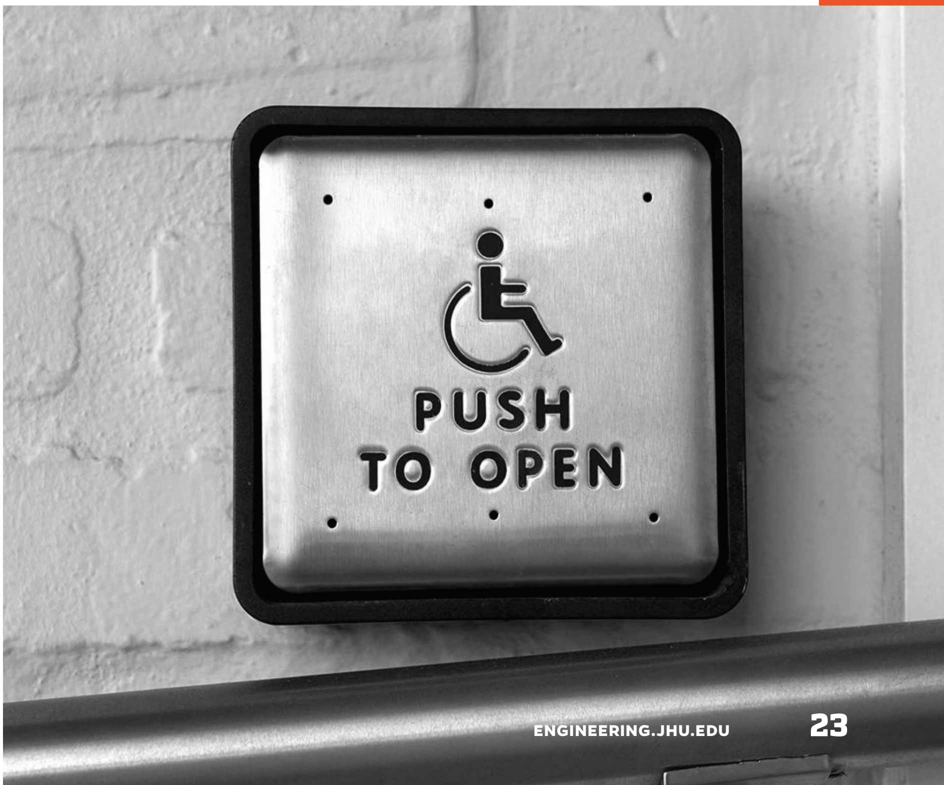
"I was afraid to get diagnosed because I thought if I had a disability, I would always be 'less than,'" she says. "But my wonderful academic adviser, Denise Shipley, encouraged me to get tested because the university can't provide accommodations without documentation of a disability. So, I finally saw a professional and was diagnosed with generalized anxiety disorder, which allowed me to register with Student Disability Services, at which point my whole perspective changed."

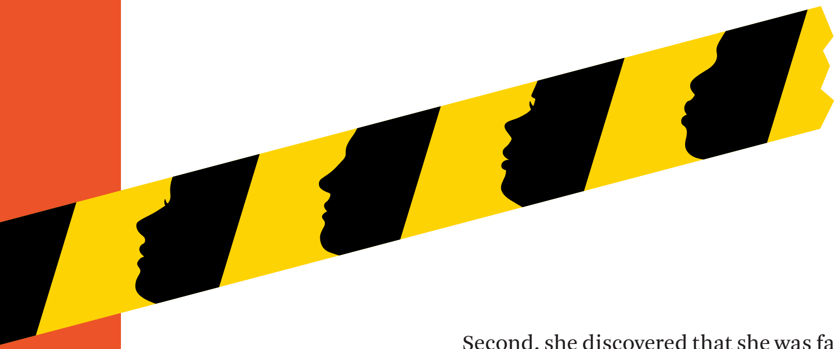
First, Ceesay got the accommodations she needed, including access to PowerPoint slides and notes as well as recorded lectures for each of her courses, which has become the norm during the COVID-19 pandemic (to the joy of other students who have trouble focusing). "I don't panic when I zone out during a lecture because I can now go back over the material and really master it," she says.

As for testing, the rustle of papers, the whispers, the small sounds other students might make to express their own worry or confusion, and even the awkwardness of lecture hall desks that don't quite fit her 5'11" frame contributed to Ceesay's panic. Now she gets more time as needed and the chance to take tests in a quiet environment—at home, during COVID-19, using technology that includes lockdown browsers all students are required to use when taking exams remotely to prevent cheating—and when it becomes possible to do things on campus, in one of Homewood's recently expanded SDS testing rooms.

"I finally saw a professional and was diagnosed with generalized anxiety disorder, which allowed me to register with Student Disability Services, at which point my whole perspective changed."

—Fatima Ceesay '21





Second, she discovered that she was far from the only person on the Homewood campus with a disability. She came to embrace the idea that, far from a stigma, disability is an aspect of identity, of our great human diversity, and deserves respect, accommodation, and care.

"Because I had such a great experience with Student Disability Services," she says, "I applied to become a student assistant at the Homewood office working with undergrads, and I have learned so much," she says. "It has challenged my ideas of what is 'normal,' and it's made me a lot more comfortable with the idea of having this so-called invisible disability."

> **"Our goal is to change the way disability is seen—not as an impairment, but as part of a student's unique identity, just like race and gender and class and all of the other differences that contribute to the richness of the culture."**
>
> **—Terri Massie-Burrell**

Creating a Flexible Environment

When Catherine Axe was hired in March 2019 as JHU's first university-wide executive director for Student Disability Services, a big priority for students was relocating the Homewood campus office. At the time, it was on the third floor of Garland Hall, a building with only one elevator.

"The SDS Homewood office has since moved to the first floor of Shaffer Hall to a larger space with an accessible, single-use restroom just across the hall," says Axe. "The new office also has expanded capacity to administer exams with accommodations and an area where students can wait for appointments or study. It was great to be able to relocate to a larger, more accessible, and functional space."

Last year, Axe also hired an assistive technology/alternate format specialist, Kamran Rasul. "Having Kamran on board is a lifesaver," says Allison Leventhal, the Student Disability Services coordinator for the Whiting School's Engineering for Professionals programs. "He knows and understands the technology that's available, so he is able to work with me and the students I serve to solve their problems. I don't have to do that kind of research, which is not my expertise. Plus, he works with all of us—students, staff, and faculty—teaching us how to use these technologies."

Leventhal is a great fan of JHU's Universal Design for Learning Initiative, spearheaded by faculty members, many of them engineers, who early on embraced the idea that teaching techniques should be as flexible as possible to accommodate the different ways students learn.

"How can we make it so fewer people need accommodations because the environment we've created is itself flexible?" Leventhal says. "Some of the technologies we recommend for students, like software that turns textbooks into audiobooks, are things I would have loved as a student, not because I identify as having ADHD, but because it's just cool."

Other benefits of technology are more efficient ways to ensure that students get the accommodations they need, and Axe and her team have implemented a new university-wide database called Accommodate to do just that. "It was a major undertaking, and it's still in the early stages," she says, "but it should make it easier for students, and for faculty who need to coordinate exam accommodations. And we've just begun to explore its potential."

'Like Being in a Dream'

Diaz, who will be a third-year student next year, says he appreciates the ease of using Student Disabilities Services.

"It's really nice because they have a letter written up with all of your accommodations, and each semester, I just send that letter to each of my professors. Otherwise, I would have to email each professor and ask them for accommodations and, because I can't write and therefore use a scribe, which means it's from my mind to their hand, it would take a fair amount of time. So, it's a very effective system," he says. "Plus, the people in the SDS office are really nice."

In contrast to Ceesay, Diaz has been disabled since middle school. An active, athletic child, he loved sports, and he loved working with his hands, helping his father, who is a machinist, fabricate things and helping him to change the oil in their car.

One Sunday when Diaz was 11, he was in church with his family, playing the piano for the service as usual, when suddenly he couldn't breathe, and his body stopped functioning. His father rushed him to the hospital, where he was put into a medically induced coma.

"Two weeks later, I woke up and couldn't move," he says. "It was like being in a dream. It's one of the few times in my life I've seen my father cry."

No one was quite sure what was wrong. At first, he was diagnosed with Guillain-Barre syndrome, a rare disorder in which the body's immune system attacks the nerves. More recently, his JHU neurologist diagnosed him with acute flaccid myelitis, possibly caused by an enterovirus. But there is no known treatment, and Diaz has been a wheelchair user, without the use of his arms and legs, ever since.

"I was an outdoors kid, always moving," he says. "When this happened, I really poured myself into my studies, especially science and math. I knew that education was the key to my future."

Because he can't physically write, he worked on improving his memory to the point where he could do complex math equations in his head. He did so well in school that he was named one of the nation's 161 U.S. Presidential Scholars and was awarded a full scholarship to JHU. His high school classmates elected him prom king and voted that he deliver their graduation speech.

Diaz would agree with Massie-Burrell that disability is only one—and maybe not even the most important—aspect of his identity. "I know people see me in the chair, and that's the outside perspective," he says. "But I try not to dwell on it."

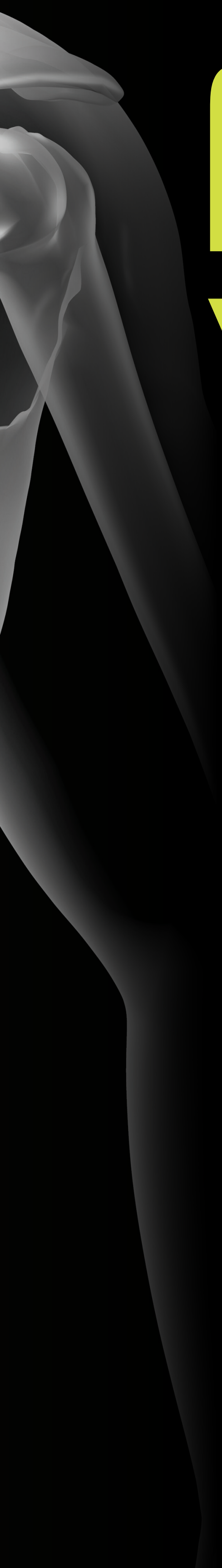
He is the child of parents who emigrated from Mexico in 1995. He has one older brother, whom he adores, who is now working as a chemical engineer and was his inspiration to study engineering. He and his brother are the first in their family to go to college. "Our parents don't have a lot of money, and it's obviously hard for me to get a job, so I rely a lot on the financial aid from school," he says. In fact, during COVID-19, his mother left her job and moved from their home in North Carolina to Baltimore to care for him because his parents worried about outside caregivers exposing him to the virus.

Diaz finds the JHU campus very accessible, though he notices that many Baltimore streets lack curb cuts and says his friends can take shortcuts on campus—up stairs, for instance—that are impossible for him. Among his accommodations were an accessible dorm room (before COVID-19, when he relocated to a nearby apartment), an adaptive tray for his laptop, testing accommodations, and permission to leave class early to get to the next class on time.

And though he is grateful for those accommodations, he doesn't expect to need them forever. AFM is a relatively new diagnosis, still poorly understood. Like Ceesay, he is majoring in chemical and biomolecular engineering. Ceesay says she chose the major because she has always been interested in medicine and wants to make a contribution to the field as an engineer. Diaz says he wants to do biomedical research. "One of the reasons I keep studying," he says, "is that I want to find a way in the future to fix myself and other people suffering from paralysis."

Leventhal says students like Ceesay and Diaz are her inspiration. "The reality is that our students at Hopkins are brilliant," she says. "They're the ones who are going to come up with the great inventions of our time. My colleagues and I in Student Disability Services are just trying to level the playing field for them, and I see that as our contribution to their incredible journeys." ▪

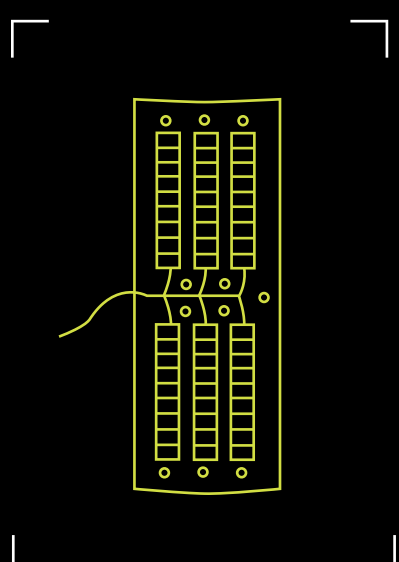
Study carrels, for student testing or studying, are just one of the offerings provided by the Office of Student Disability Services.



BACK(S) TO LIFE

Those with spinal cord injuries are often plagued by pain and paralysis. An ultra-high-tech spinal implant being developed by Johns Hopkins engineers could dramatically improve that bleak reality—and transform clinical medicine.

by **JIM DUFFY**



AMIR MANBACHI

NICHOLAS THEODORE

Five years ago, Johns Hopkins neurosurgeon Nicholas Theodore brought a problem with echoes of the movie *Groundhog Day* to biomedical engineer Amir Manbachi, who was then teaching in the Undergraduate Design Team program at the Whiting School.

An expert in spinal cord injuries, Theodore was frank in noting that no significant new drugs or treatments had been developed over the previous half a century. In spinal cord injury repair, he told Manbachi and his students, surgeons are still doing "the same rudimentary things that we've been doing for 50 years."

In the aftermath of an injury, they open up a patient and "decompress" the spinal cord, clearing out stray pieces of bone and pockets of hematoma to stabilize the spine. After surgery, they monitor blood pressure very carefully, tinkering frequently in an effort to reduce the risk of dangerous secondary injuries. Otherwise, however, the treatment regimen is mostly a matter of helping patients adjust to new realities marked by pain and paralysis.

Theodore's pitch to the Design Team program was that the way out of this *Groundhog Day* predicament might well be achieved through biomedical engineering. He wanted a team of Whiting School students to develop a map pointing the way toward better outcomes for spinal cord injury patients.

> "The cellular cascade that happens in the immediate aftermath of injury is just the beginning. After that come secondary injuries—loss of blood flow, loss of oxygen, inflammation, and scar tissue forming."
>
> **NICHOLAS THEODORE**

The pitch was a hit—one of the most popular proposals among the 20 or so options presented to students that year. In short order, Manbachi was supervising the work of a team headed by engineering student Ana Ainechi.

The map that emerged from that capstone project is still in play, though it has evolved over time into a highly ambitious undertaking. Late last year, Theodore and Manbachi received a five-year, $13.48 million grant from the Defense Advanced Research Projects Agency at the U.S. Department of Defense. Best known for its funding in the 1960s of ARPANET, a key precursor of the internet, DARPA specializes in supporting high-risk, high-reward projects.

This one aims to develop a one-two punch of cutting-edge devices with the potential to revolutionize both diagnostics and treatment in spinal cord injury cases.

That happy ending, however, will come to pass only if the team that Manbachi and Theodore have assembled can overcome a string of daunting challenges that run the gamut of engineering specialties: materials, acoustics, electronics, and more.

Can they create a new ultrasound device with the groundbreaking capacity to detect what's going on inside the microvasculature around the spine? And can they do this with wireless and biocompatible materials, as the concept is to stick that machine on the spinal cord in the manner of a tiny Band-Aid armed with thousands of electrodes? Will they be able to outfit a catheter with a groundbreaking fiber optic array that gives physicians real-time, bedside readings of pressure, temperature, and oxygenation levels deep inside of microenvironments around the spine?

"This is as pioneering as it gets," Manbachi says. The work that began in an undergraduate educational setting is now in the hands of a multidisciplinary team that includes not just scientists at the Whiting School and the School of Medicine, but also Johns Hopkins' Applied Physics Laboratory, Columbia University, and a top-of-the-line private technology firm. Former student leader Ainechi is on the team too, from her new perch as a graduate student.

"The way this began is very important to me," Manbachi says. "The work students do can make it seem like engineering is all about coding and writing scripts and textbook materials. It's in projects like this that they come to see how this field can actually help people."

ONE-TWO PUNCH

The lack of progress in spinal cord injury repair does not reflect a lack of effort. Scores of drugs have entered clinical trials in recent decades. In the early 2000s, stem cell therapies seemed tantalizingly close to making a difference at the bedside. "I don't mean to be a nihilist. But the fact is, nothing has worked," says Theodore.

Over time, Theodore developed a theory about that run of failure. The injuries involved in these cases usually involve multiple, interrelated biological events of dizzying complexity. "The cellular cascade that happens in the immediate aftermath of injury is just the beginning," says Theodore. "After that come secondary injuries—loss of blood flow, loss of oxygen, inflammation, and scar tissue forming." Those secondary cascades often bring on new levels of paralysis.

"If you've got 50 holes in a dike and you stick your finger in one of them, you're still going to drown," he says. Therein lies the problem that Theodore brought to the Whiting School five years ago: Can biomedical engineers help to bring that entire flood wall and all of its interrelated holes into focus?

The solution envisioned in the DARPA project involves a pair of devices. One is a catheter; the other is ultrasound. If engineers succeed in making these novel devices work as planned, the one-two punch will open up a wealth of biological data, delivered in real time with an astonishing level of detail.

"We'll be able to see, in great detail, what's happening with blood flow and oxygenation in the tiniest microvasculature of the spinal cord," Manbachi says. Such an instantaneous diagnostic treasure trove will put clinicians in a much stronger position to anticipate and prevent those secondary cascades—and, perhaps, to accomplish more.

A CATHETER LIKE NO OTHER

The "acute" phase after a spinal cord injury—the two weeks or so after decompression surgery—is fraught with risks that are difficult to predict and often impossible to prevent. Physicians monitor blood pressure very carefully in this period, tinkering frequently to make sure nothing is awry with perfusion and blood flow. During surgery, they also install a lumbar drain that helps maintain healthy fluid levels after the operation.

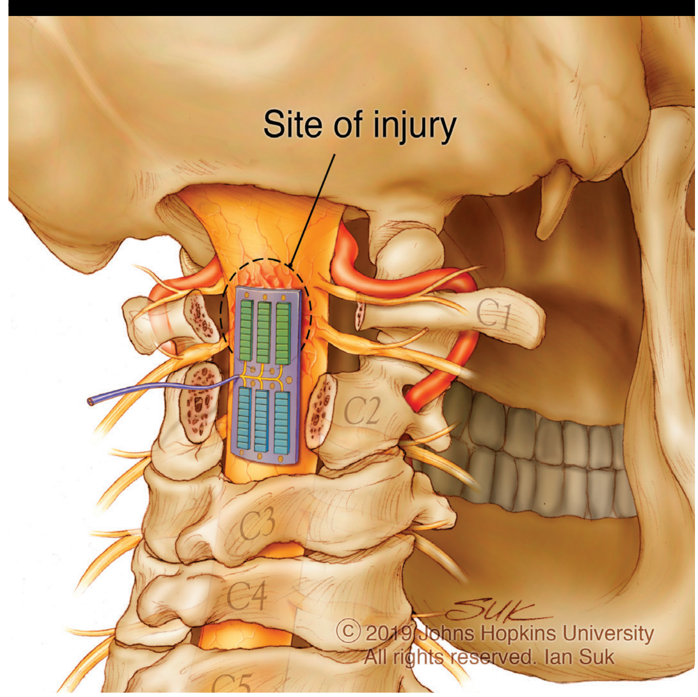
This catheter is what's being transformed in the first of the one-two punch combination. Work now underway at the Applied Physics Laboratory and the Whiting School aims to turn that catheter into a high-powered diagnostic tool equipped with a trio of fiber optic cables. One would read fluid pressure. Another would track temperature. The third would measure oxygenation.

But the spine is a difficult environment to monitor with current technologies. In brain injury, Theodore notes, surgeons drill a hole in the head and insert a tube in the fluid-filled space of the brain, gauging intracranial pressure. "But the anatomy of the spinal cord is different —its diameter is about the size of your pinkie finger," says Theodore. "I can't stick something into the spinal cord without causing injury." The way things stand now, he adds, surgeons are "up on a tightrope with a blindfold on."

That blindfold might come off with localized measures of pressure. "The ability to see what's happening with pressure in blood vessels that are smaller than a human hair would create tremendous opportunities for progress," he says.

SITE OF INJURY

THE MULTIFUNCTIONAL IMPLANT BEING DEVELOPED WILL BE PLACED AT THE SITE OF A PATIENT'S INJURY.



The third data point—oxygenation—presents an especially daunting engineering challenge, says Steve Babin, a physician, electrical engineer, and senior APL researcher. Today, the only way to get an oxygenation number like that is by shipping a sample off to a lab. That leaves physicians operating on information that is at least several hours out of date.

But the only way to measure oxygenation via fiber optics will be through a proxy chemical present in the fluid flowing through the lumbar drain. This notion that fiber optics can be used to find biomarkers continuously is relatively new, but Babin has a record of success, as he is the inventor on a Johns Hopkins patent for a fiber optic sensor that was subsequently shown to measure the compound bilirubin, something that's of great interest in neonatal intensive care units.

A number of chemicals would be good candidates for the role of oxygenation proxy, but the challenge is finding the right balance between accuracy and feasibility. Different chemicals absorb light in different quantities and at different wavelengths, so their presence can be detected by measuring how much light makes a return trip through the catheter after hitting a retroreflector. This method allows fast, real-time, in situ, and—crucially, in a challenging environment like the spine—safe biomarker measurement.

"That will tell us what the concentration of that chemical is," Babin says, "but we need to find the right chemical, the one that has wavelengths that are in an area that we can access, technologically." The winning candidate from this pool of chemicals has yet to emerge.

Other technical hurdles loom on the catheter horizon. The logistics of fiber optics mean this souped-up catheter can't be inserted with a traditional needle. Medical device expert and microelectronics process engineer George Coles of the APL team is developing a brand-new way of inserting the catheter.

Another question surrounds the thickness of the fiber optic cables: How much will the cables inhibit fluid making its way through the drain?

"Nick sometimes needs all the capacity that's in the drain," Manbachi says. "We're still figuring that out too, experimenting with different elasticities."

Biomedical engineer Francesco Tenore is confident the APL team is on the road to meeting all these challenges. "When physicians are able to see these results coming in continuously in real time, that's going to be a medical first," he says. "It's going to provide them with immediate feedback on their therapies, so that they can alter and modify it."

BRINGING ULTRASOUND TO A NEW ENVIRONMENT

Ultrasound made its first splash in medicine during the 1970s, once the invention of rudimentary scanners gave physicians a way to visualize the information available through high-frequency sound waves. In short order, it became an everyday tool across scores of specialties. Think fetal imaging in obstetrics, echocardiograms in cardiology, and bone sonometry in orthopedics.

Manbachi's team is looking to push ultrasound into uncharted territory by imaging the microvasculature around the spine. The largest spinal arteries are tiny as can be, measuring in the neighborhood of 200 microns. Countless even smaller tributaries run this way and that from such main lines. In tight quarters like this, blood moves more slowly than it might through an artery like the carotid, which measures about 1 centimeter.

"A typical ultrasound probe might run between 5 and 10 megahertz," Manbachi says. "We're looking at running this between 20 and 33 megahertz, because we're going to need to really push those limits to make sure we can see what we need to see."

> "A typical ultrasound probe might run between 5 and 10 megahertz. We're looking at running this between 20 and 33 megahertz, because we're going to need to really push those limits to make sure we can see what we need to see."
>
> **AMIR MANBACHI**

The environment is not the only groundbreaking aspect here. The device will need to win regulatory approval as biocompatible, since the plan is for surgeons to attach it to the spine during decompression surgery. (The implanted device will not use bulky batteries. Instead, it will be wirelessly powered from a nearby relay station, outside of the body.)

Making matters more complicated is the human spine itself. It might look rigid on a classroom skeleton, but inside a living body it's constantly pulsating along its entire length. The rates vary, not just among different people, but within a single individual, especially one who has been through recent injuries and surgeries, and is probably still adjusting to new medications.

"This is going to be a big acoustic engineering challenge," Manbachi says. "How do you keep your aim on the right focal point when the whole spine is pulsing like that?"

No ultrasound machine has ever operated amid the distractions and complications of a living environment like this. How will the flow of spinal fluid affect sound waves? What will happen to those waves as that flow fluctuates because physicians are adjusting the amount of fluids being drained through a catheter?

The broader scientific team tackling these challenges includes radiologists, neurosurgeons, and neurologists in addition to biomedical engineers. A multidisciplinary subteam is housed at the private-sector firm, Sonic Concepts, that will build the actual devices, which will measure just 1 centimeter by 2 centimeters while armed with a full array of thousands of ultrasound transducers.

The end goal is to have a device ready for human testing on the ambitious five-year timeline of the grant.

A THERAPEUTIC TOOL

The potential this device holds for improving patient outcomes is enormous. Armed with detailed, highly localized three-dimensional imaging, physicians will be in a much stronger position to gauge the risk of secondary injuries associated with scarring, inflammation, and other post-injury phenomena. These biological "cascades" have devastating long-term impacts, turning a patient who may initially have lost the use of an arm or a leg into a paraplegic or quadriplegic.

Paralysis sets in among spinal injury patients when the body loses its knack for autoregulation, no longer able to figure out how much blood should flow through this artery and when this or that electrical impulse should fire.

The ultrasound device envisioned in this project will do more than help physicians monitor these risks; it will also operate as a therapeutic tool. When signs of neurogenerative failure appear, physicians will be able to step in with "focused ultrasound." Manbachi compares the neuromodulation nudge this delivers at the cellular level to a gentle tap on the cheek to a person who is nodding off to sleep.

In addition, recent laboratory work has explored the use of electrodes to drive electrical stimulation along the spine, which puts electric stimulation therapy on the table as well. That approach may or may not live up to its potential—only time will tell. For now, Theodore prefers to keep his eye on the prize of incremental improvements.

"If we can change just those secondary outcomes, saving something like arm mobility, it will make a big difference for patients." he says. "We'd all love to find a way to 'cure' spinal cord injury. But our first steps toward good therapeutics will be baby steps, and we need to remember that those are going to help patients too."

'SYSTEM OF SYSTEMS'

Everyone involved in this project senses that the completion of the five-year journey through DARPA is more likely to mark a beginning than an ending. Manbachi views the destination here as a "system of systems" where ultrasound and fiber optics are linked and communicating, and data gathering is happening on the machine-learning level.

APL's Tenore is looking forward to the day when new patients can benefit from readings gleaned in thousands of prior patients. "This opens up the possibilities of bringing machine-learning algorithms to bear here," he said. "That, in turn, opens the way to personalized medicine, as it will become quickly apparent in many cases how any given patient differs from 'the norm.'"

As the new devices get up and running, specialists in other fields are bound to take note. "Spinal cord injury is our focus here, but it's not limited to that down the road," says Tenore. "If we demonstrate that we can use these technologies to track these biological changes in real time, that opens up a lot of other possibilities."

Theodore agrees: "The ability to make these measurements in a microenvironment with implantable devices might end up being used in the brain or on the liver—who knows where else? We're working at the tip of a very big iceberg here. I really believe that this has the potential to transform clinical medicine."

Says Manbachi: "I've always dreamed of becoming an engineer whose work actually helps patients at the bedside. I feel like this grant is giving me an opportunity for that dream to come true." ■

STAKES IN SPINAL CORD INJURY

Nearly 200,000 Americans suffer serious spinal cord injuries every year, mostly due to auto accidents, falls, and violence. Mortality rates are quite high through the first year after an accident, especially due to cardiovascular complications.

Those who survive—and there are about 300,000 living with old injuries in any given year—face elevated risks for potentially fatal complications associated with blood clots, pneumonia, and urinary infections. Life expectancy among these survivors is markedly lower than that of the general population.

TikTok Tutoring—and More

BEN STRAUS '21 JOINED TIKTOK FOR THE SAME REASON MOST OF THE PLATFORM'S 1 BILLION USERS JOINED: to be entertained, follow popular influencers, and maybe pick up a few life hacks. Eventually, though, Straus began creating his own fun videos, and soon, the fourth-year biomedical engineering student decided to use his expertise to help middle school, high school, and college students around the world learn more about engineering.

"I realized that, in high school, I had very little knowledge of what engineering actually was," says Straus. "In college, I've learned about the field, picked up many tricks, and made many study guides that students might find helpful."

In late January, he knew he had struck on an idea that resonated with an audience after an initial short video announcing his first live session had been viewed more than 100,000 times and his account had gained more than 3,000 followers—all in fewer than 24 hours. So Straus started creating videos in which he answered questions his followers sent him about engineering, college life, and study tips, along with the quintessential dance or voiceover videos. One video attracted more than 900,000 views in nine hours.

He holds live TikTok "office hours" every Monday evening, during which Straus explains what biomedical engineers do, why he chose this field, what he plans to do after graduating, how he studies and keeps track of deadlines, how he stays motivated and organized, and more.

His TikTok following has now reached more than 125,000 people across the United States, Canada, and the United Kingdom. "The growth has been exponential, and I hope it continues so that I can keep helping students," says Straus.

With a solid following on TikTok, he decided to form an interactive learning community on Discord, a chat platform used by many students as a place to go to offer and receive homework and study assistance. Ranging from middle school to college-level students located around the world, the members of Straus' Discord group comprise an open community that caters to different learning styles. Any member can post a question, and any member can answer it via text or live chat.

Straus graduated in May with his bachelor's and master's degrees, and he is beginning his career as a systems engineer at Medtronic in Minneapolis, but he plans to keep up his TikTok tutoring and even begin small-group sessions. "I have always found tutoring and mentoring to 'feed my soul' in a way, and I won't stop after graduation," he says.

— **SARAH TARNEY**

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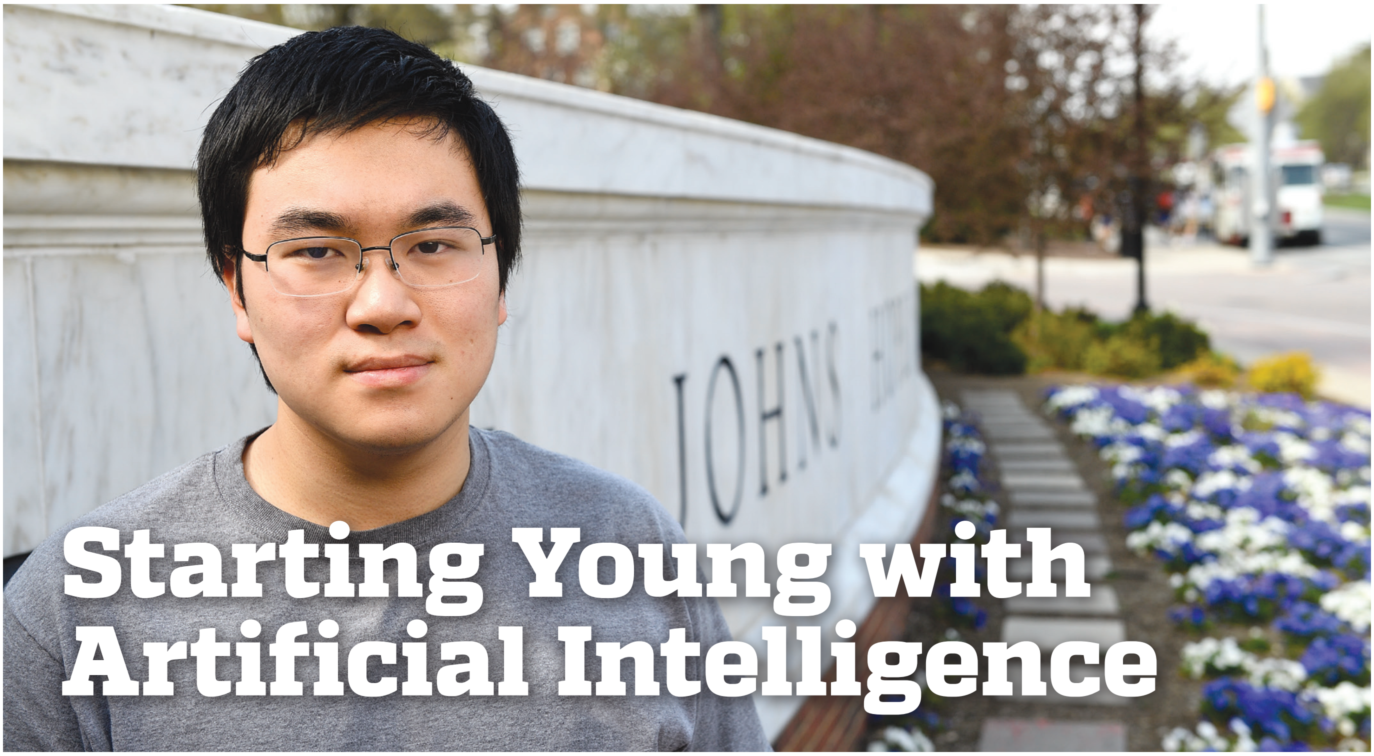

Starting Young with Artificial Intelligence

AS A HIGH SCHOOL SOPHOMORE IN UPSTATE NEW YORK, NATHAN WANG BEGAN TAKING CALCULUS classes at Rensselaer Polytechnic Institute. Eventually, his desire to apply math to practical problems grew into a fascination with artificial intelligence. Before starting at Johns Hopkins last fall, his project on using deep learning to improve ultrasound tumor ablation advanced to the finals of the 2019 Intel International Science and Engineering Fair.

"For me, AI was the catalyst that finally revealed to me how math and science influence practical technologies, and I was convinced it could have the same motivating effect for other high school students," says Wang, who just completed his first year majoring in biomedical engineering and in applied mathematics and statistics.

"Very few high schoolers have a real depth of knowledge in AI, not because it's especially difficult, but because there are few resources geared toward them and they don't know where to start," says Wang. So he set out to change that.

During his June 2019 participation in Boys Nation, a weeklong deep dive into government in Washington, D.C., for 100 young men selected nationwide, Wang presented a bill he had drafted on K-12 AI education to his congressman, Rep. Paul Tonko (D-NY). Tonko, an engineer, saw the potential and invited Wang to work with his office to incorporate his idea in the National Defense Authorization Act.

The bill, which became law on Jan. 3, 2021, includes the AI Education Act, which directs the National Science Foundation to offer grants and other support to develop AI-related curriculum and programs for K-12 students to gain AI skills, experience, and a deeper understanding of the field's ethics and social implications.

Now, Wang is working with researchers at Johns Hopkins and Stanford to create AI courses for high school students in Baltimore and across the nation. "AI inspired me to pursue a career in science, and I know it will have the same effect on other students," says Wang, who aims to serve as an intern in Tonko's office this summer to continue his advocacy for AI education.

"As an illustration, imagine you are trying to build a house," he explains. "Even if you have all the raw materials, it's impossible without tools. Similarly, students have sufficient raw knowledge in math, biology, chemistry, and engineering, but how can you expect them to construct innovative solutions without being aware of the powerful computational tools literally at their fingertips?"

— SARAH ACHENBACH

"My goal in creating HSWET was to help students identify the ways that they can mold their undergraduate education to prepare for careers in renewable energy."

— WILLA GRINSFELDER

An Energy for Change

LIKE MANY HER AGE, WILLA GRINSFELDER '21 GREW UP WITH THE UNDERSTANDING THAT SHE IS LIVING in a world with a rapidly changing climate. In high school, she led canoeing trips for young women in the lake country of northern Minnesota. After starting college, over the course of three summers, she watched the weather and ecology of a place that she loved change drastically; large storms took down many of the area's white pines, and lake levels seemed to drop each year.

"Climate change isn't an abstract concept anymore. We're experiencing it ourselves, and students come to Johns Hopkins looking for ways to address the catastrophes they've seen in their own communities or heard about across the globe," says Grinsfelder, a mechanical engineering student.

While a third-year student at Johns Hopkins, she volunteered at Southwest Baltimore Charter School, where she mentored students through the process of designing wind turbine blades, and she gained a better understanding of how she could play a role in wind energy. Now, she is helping like-minded students prepare for careers in the renewable energy industry through the student-run Hopkins Student Wind Energy Team, which she co-founded last year.

"In our classes and labs, we learn the technical skills, but there's still a knowledge gap regarding what it really looks like to be an engineer working in renewable energy. My goal in creating HSWET was to help students identify the ways that they can mold their undergraduate education to prepare for careers in renewable energy," says Grinsfelder.

With 25 members from several departments, HSWET is now focused on preparing to compete in the 2021 U.S. Department of Energy's Collegiate Wind Competition, to be held in June. The team is tasked with designing and building a miniature wind turbine, developing a plan for a hypothetical 100 megawatt wind farm in South Dakota, and hosting outreach and networking events.

Grinsfelder is one of three students leading the wind turbine design portion. Since the competition will be held virtually this year, the team will test its turbine in the campus wind tunnel in Maryland Hall and present its results at the American Wind Energy Association's CLEANPOWER virtual conference in June. But the team is not just about competing: Grinsfelder hopes it will also provide students with resources and connections at Johns Hopkins and beyond. During the fall semester, she recruited industry mentors from GE Renewable Energy and other companies.

After graduation, Grinsfelder will intern at Natel Energy, a California-based startup that develops innovative hydropower systems. Eventually, she envisions herself in a position where she can work on mechanical design of wind energy systems.

— CATHERINE GRAHAM

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Increasing Access to IVF

Micajah McGarity

THE COVID-19 STAY-AT-HOME ORDERS IN MARCH 2020 SHUT DOWN THE RESEARCH that Micajah McGarity, a PhD candidate in the geography and environmental engineering program, had been doing on the environmental health drivers of infertility. McGarity, MSE '12, had been focusing on creating optimization models to make fertility services more widely accessible.

Then it hit him. His research could be used to help improve testing access for COVID-19. "At the time, there was a big need for improved access to COVID testing," says McGarity, the M. Gordon Wolman Fellow. "I had the infrastructure in place, so I began searching for lists of drive-up COVID-19 testing centers across the country."

Using data from GoodRx, a website and mobile app that finds discount prices for medications, McGarity determined that opening 250 new center locations in optimal locations could extend drive-up testing to within a 60-minute drive for about 100 million people around the United States. He created the COVID-19 Drive-Up Testing Dashboard, hoping to provide information that would assist Johns Hopkins and other national public health agencies in responding to COVID-19.

More recently, McGarity has returned to addressing disparities in fertility treatment access—which is much more than an exercise in optimization methodology for him. He and his wife, Sara (who he met working in the same research group at Johns Hopkins), are among the approximately one in eight couples affected by infertility in the U.S. Their experience inspired McGarity's research focus when he enrolled in the Whiting School's part-time PhD program in the Department of Environmental Health and Engineering. An operations research analyst at Johns Hopkins' Applied Physics Lab, McGarity uses the tools of optimization, probability, and statistics to improve the safety and security of U.S. Navy submarines.

"My wife and I were lucky and didn't have issues accessing fertility care, but I learned that most couples in the U.S. are not so lucky, with only about 40% of demand met for in vitro fertilization," says McGarity, who holds a WSE/APL Research Assistantship. "Of the many barriers to access, I found that about 29% of those in the reproductive age population do not live in an area with an IVF clinic, and I knew that I could apply engineering to the challenge of increasing access."

He collected data from every U.S. fertility clinic to create the national Fertility Clinic Finder. Currently, he's developing a dashboard like the one he created for COVID-19 testing locations to help existing and new reproductive endocrinologists determine the optimal placement of new clinics. The McGaritys, who have two children, used his data to find a new clinic for continuing treatment once the clinic they were using closed permanently in summer 2020 due to the pandemic.

— SA

“He has so much more confidence, his memory is better, he learns more quickly. I see him redefining what it means to have Down syndrome.”

- NIK NIKIC

Redefining Down Syndrome

NIK NIKIC ’84 LEARNED EARLY TO SEE BEYOND LIFE’S APPARENT LIMITATIONS. HIS PARENTS, WHO WERE subsistence farmers in rural Montenegro, moved their family to the Bronx when he was 10. His mother worked nights as a housekeeper, and his father worked days doing maintenance, in pursuit of a brighter future for Nikic and his two younger brothers. He vividly remembers his mother predicting, when he was only 6, that he would study hard and have great success as an engineer. “They taught us to work hard, and they taught us to dream,” he says.

After earning his degree in electrical engineering, Nikic applied those lessons to a rewarding career in technical sales and the creation of his own consulting firm. But perhaps their most spectacular application has been his work with his son, Chris, who last Nov. 7 became the first person with Down syndrome to finish an Ironman triathlon.

As far as anyone knows, Chris is the first person with Down syndrome even to attempt the grueling event, a 2.4-mile open-water swim, 112-mile bike ride, and 26.2-mile run, all done with no breaks in fewer than 17 hours. But after years of listening to expert advice and watching his son struggle to find his place in the world, Nikic had an epiphany: What if the experts were wrong about the things they said Chris couldn’t do, like balance himself on a bicycle? Or live on his own?

At 21, Chris Nikic has his own dream—to live independently, with a house and a car and a wife as beautiful and loving as his mother, Patty. What if he could gain the confidence to begin down that road to independence by doing something no one else with Down syndrome had ever done before?

About two years ago, Chris began his training with a single pushup. Because Nik is professionally interested in metrics, he started measuring his son’s progress and noticed he was improving, just very slowly. So, their mantra became 1% improvement every day. And Nik learned something new—that Chris’ learning curve is simply different, but in the long run, it’s as effective as anyone’s.

Despite crashing his bike, being attacked by fire ants, and suffering tremendous physical pain, Chris Nikic finished the momentous event (qualifying for a Guinness World Record) and has since done countless interviews, learned to give speeches (memorizing one sentence a day), and become an inspiration to his peers.

“He has so much more confidence, his memory is better, he learns more quickly,” Nik says. “I see him redefining what it means to have Down syndrome.”

— JOAN KATHERINE CRAMER

UNICEF: In Good Hands

Ann Thomas

IN THE AGE OF COVID-19, WE HAVE BECOME HYPERAWARE OF HYGIENE AND HOW QUICKLY serious disease can spread and cripple the world. And though this has been a painful lesson, it is also a highly valuable one, says Ann Thomas, MS '02, who has spent the last 20 years promoting hand-washing with soap and other sanitation practices in developing countries.

"In parts of the world where access to vaccines and health care services is challenging, we promote hand-washing with soap (after visits to the bathroom and before eating food) as a way to cut rates of illness in half," says Thomas, who, after years of running water, sanitation, and hygiene programs for UNICEF in Eastern and Southern Africa and Indonesia, was recently named the organization's senior adviser for sanitation and hygiene. In this role, she sets global strategy on sanitation and hygiene out of the New York headquarters of UNICEF, an organization working in more than 190 countries to save and improve children's lives.

Growing up in Ottawa, Canada, Thomas knew she wanted to work in international development but wasn't sure what her role might be. After graduating from McGill University with a biology degree, she moved to Washington, D.C., to do an internship with the World Health Organization and decided to study environmental engineering at Johns Hopkins through what is now known as the Whiting School's Engineering for Professionals programs. There, she took a class with noted epidemiologist Les Roberts, who introduced her to the significance of sanitation.

"It was my introduction to the fact that the investments in sanitation and clean water we take for granted are only about 150 years old and that in the developing world, people are still dying of 19th-century diseases, like cholera and typhoid, and that diarrhea is still a leading cause of death for children under 5," she says.

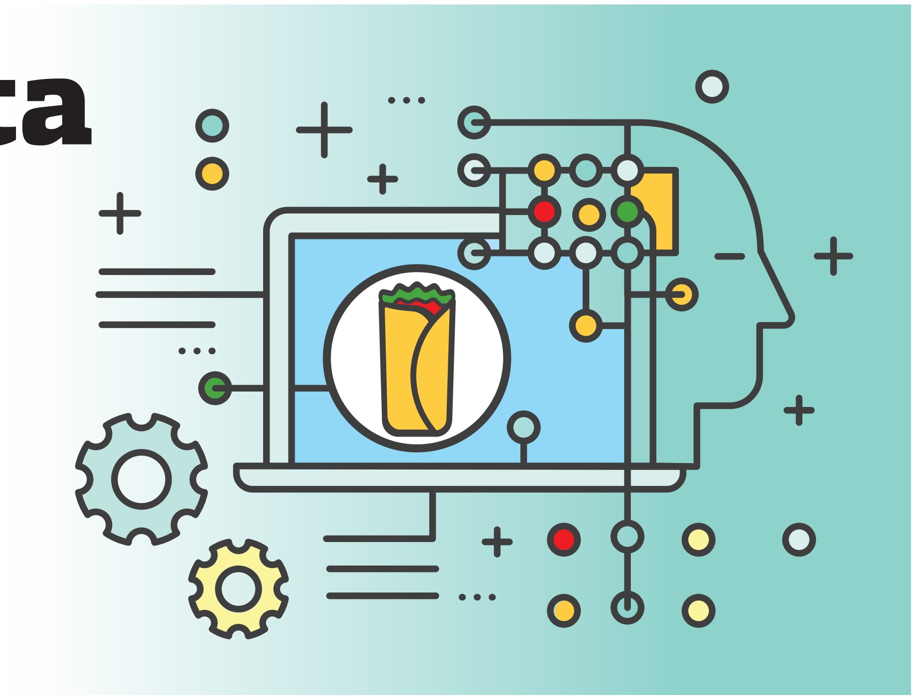
Most governments don't want to talk about—much less invest in—sanitation, says Thomas, so she and her colleagues deploy multipronged campaigns that include everything from commissioning studies to organizing high-level conferences with peers from countries that are spending more and achieving better health outcomes.

During her recent posting in densely populated Indonesia, where a large majority of people living in urban areas rely on individual wells and unsealed septic tanks, she worked with the government on studies detailing the extent of cross-contamination of leaky septic tanks into water systems and the resulting vulnerabilities this situation presented to households.

"After years of inaction in this particular area of safety, we were able to convince the government to include targets for safely managed sanitation for 20% of their population in their new five-year national development plan," says Thomas. "This gets them on the ladder of committing resources and taking action, which is a huge step forward."

— JC

The Data Behind Your Burrito



AS LEAD DATA SCIENTIST AT CHIPOTLE, MASH SYED, MS '15, OFFERS IN-DEPTH DATA ANALYSIS TO THE company's executives to help them make informed business decisions—expertise that took on new value with the onslaught of COVID-19.

"The pandemic has been horrible," says Syed. "But in terms of how our business has had to shift and pivot, it's been really, really interesting to try to understand the effect of the pandemic on our sales, our customer base, how people's buying behavior changes, the impact of weather, and the impact of the combination of COVID and weather." All of these factors, he says, "have changed our business dramatically."

In the early months of the pandemic, Syed built a machine-learning model—using publicly available data from Johns Hopkins and other sources—that assesses the impact of COVID-19 on the company at the county level. The model helped Chipotle leaders determine, for example, at what point it was safe to ask employees to return to work in a specific region. Over the year-plus that the pandemic has unfolded, Syed says the company has seen a "massive shift" in customer behavior, with many more customers relying on the Chipotle app to order in advance, rather than stand in line. He believes that trend is here to stay.

In some ways, Syed considers himself to be a "nontraditional" data scientist. After earning a bachelor's degree in business administration in 2004, he built a successful real estate brokerage in Northern California, but over time, he began to feel more drawn to the quantitative sciences. In 2009, he returned to school to take several foundational courses in computer science, and then in 2013, he was accepted into Johns Hopkins master's degree program in computer science, "which was transformational," he says, noting that the Introduction to Data Science course "really solidified my interest in data science."

After completing his master's degree, Syed worked as a business intelligence analyst for LA Fitness, and then as a data science consultant at Slalom Consulting. He joined Chipotle in 2019 and has been instrumental in building a new data science team for the company.

— WILL HOWARD

Mash Syed

In the early months of the pandemic, Syed built a machine-learning model—using publicly available data from Johns Hopkins and other sources—that assesses the impact of COVID-19 on the company at the county level.

When Life Gives You Lemons

Alex Bishop, who ressearches fuels for rocket engines and hypersonic vehicles at ERG, drove his first Lemons in 2016.

> "Only cars that cost $500 or less can compete. My brother found ours on Craigslist, and we prepped it by cutting the roof off and adding a roll cage, electrical cutoff switch, and fire extinguishers."
>
> **— ALEX BISHOP**

ALEX BISHOP WAS JUST A KID WHEN HE FIRST EXPERIENCED THE heart-pounding thrill of navigating a race car around a track through Gran Turismo, an auto racing video game.

Now Bishop, associate staff engineer in the Whiting School's Energetics Research Group, burns rubber at speeds of up to 115 miles per hour in real life from behind the wheel of a souped-up 1987 BMW E30. He's part of a team that competes in 24 Hours of Lemons, a road race held twice a year at the High Plains Raceway outside of Denver.

"The event is themed after the famous French endurance race, though much less serious," he says. "Only cars that cost $500 or less can compete. My brother found ours on Craigslist, and we prepped it by cutting the roof off and adding a roll cage, electrical cutoff switch, and fire extinguishers."

Members of team Panda Expresso also painted the vehicle dark brown and adorned it with decals designed by a Colorado artist and stickers from businesses. A week before the race, the team holds a fundraiser at a Fort Collins brewery, with a percentage of sales of Sad Panda stout beer benefiting the World Wildlife Fund.

"The whole thing is a lot of fun. Winning was never the point of the event, though some people get very competitive," he says.

Though the real LeMans is a 24-hour event, Lemons is split into two eight- to 10-hour days, with each team member driving for an hour or two at a time. The course is challenging, with numerous twists and turns and surprising elevation changes.

"My first time around, I was a passenger, and I didn't expect all the up and down G-forces," Bishop says. "It's nothing crazy, but it definitely makes it more interesting."

Though the pandemic prevented him from racing in 2020, Bishop hopes 2021 will find him back behind the wheel.

— LISA DENIKE ERCOLANO

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Lawn Care Made Safer

Mowing the lawn is a quintessentially American activity. But for those living with blindness, this seemingly mundane chore can be a dangerous challenge.

In response to a request by Blind Industries and Services of Maryland, a team of mechanical engineering students is designing adaptive technology to allow blind individuals to carry out this task more safely. The students are outfitting a standard lawnmower with a system that detects the height of grass ahead and cues the user through movement of a set of handlebar-mounted keys. It alerts them to any obstacles through the use of audio “beeps” that are transmitted through headphones.

“Our goal was to come up with a solution that was easy to use, made the task safer, and put a smile on our clients’ faces,” says Reginald Orbih, who teamed up with students Jungin Eugene Kim, Itic Tinman Munne, and Marcos Schwartz on the project.

— LISA DENIKE ERCOLANO