THE JOHNS HOPKINS WHITING SCHOOL OF ENGINEERING MAGAZINE

JHUENGINEERING

WINTER 2024

Material Matters

Probing the atomic structures of materials to reshape fields from energy to oncology.

Dear WSE community,

THE START OF A NEW ACADEMIC YEAR IS ALWAYS EXCITING. BUT THIS FALL—A TIME WHEN AI AND DATA science underpin so many of our endeavors—is particularly energizing.

In this issue, you'll read about a new institute for data science, artificial intelligence, and machine learning (p. 2) that will have a truly transformative impact on the Whiting School, allowing us to nearly double the size of our faculty over the next five years.

This accelerates our progress toward achieving the vision we collectively developed for the Whiting School. We committed to building out core areas of research—not only in artificial intelligence, data science, and machine learning—but also in bioengineering, energy, the environment, and resiliency in extreme environments, all aimed at improving the lives of individuals and empowering communities to thrive. Growing at such a scale will mean we can enhance our offerings and reputation in all these fields. With this transformational investment, we can execute our vision of moving from a high level of excellence to one of preeminence among engineering schools worldwide.

Our expansion will have a ripple effect, given that each new faculty member will also attract more doctoral and master's students, more postdocs, and more support staff. To underscore the magnitude of this growth and its significance for our school, consider where we stood a decade ago. Back then, the Whiting School ranked around 45th among engineering schools in terms of faculty numbers. Fast forward to today, when we are 25th in size. And in five years, we expect to be one of the largest engineering schools in the country.

We are living in an incredibly exciting time for the Whiting School, which presents us with an exceptional opportunity to positively impact not only our local community and region but also the world. This unprecedented investment will ultimately increase our ability to further excel in every aspect of our activities.

Best wishes,

T E Schlesinger

ED SCHLESINGER
Benjamin T. Rome Dean

CONTRIBUTORS

CHRISTINA HERNANDEZ SHERWOOD

'INNOVATION AT THE CROSSROADS' (P. 20)

Sherwood is a freelance writer based in the Philadelphia area who holds a master's in journalism from Columbia University. She writes health and sciences stories for a variety of academic medical centers and universities, including *Penn Medicine* magazine, *Columbia Medicine* magazine, Weill Cornell Medicine's *Impact* magazine, and *The Physiologist Magazine.*

HOWARD KORN

'INNOVATION AT THE CROSSROADS' (P. 20)

Photographer Howard Korn, who works from Baltimore, shoots for a variety of clients across the globe, "capturing real people doing real things." His clients in academia include Johns Hopkins Medicine, Kenyon College, University of Chicago, University of Pittsburgh, and Carnegie Mellon University.

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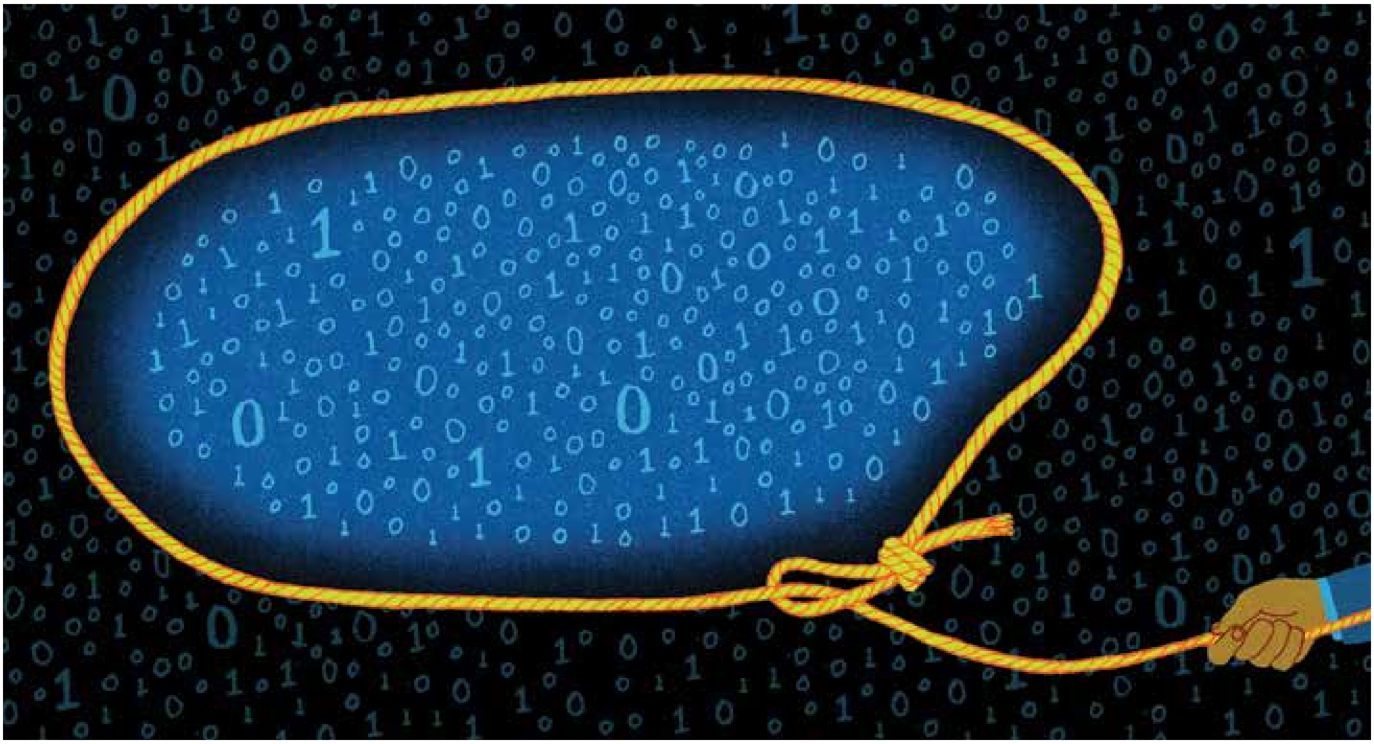
Cover photograph by Chris Vaccaro.



Transformational Investment in Data Science and AI

IN AUGUST, JOHNS HOPKINS ANNOUNCED A MAJOR INVESTMENT IN DATA SCIENCE AND THE exploration of artificial intelligence.

The heart of this endeavor will be a Whiting School of Engineering–based interdisciplinary data science and translation institute that will significantly strengthen the university's capabilities to harness emerging applications, opportunities, and challenges presented by the explosion of available data and the rapid rise of accessible AI. The initiative also will transform the Whiting School, effectively doubling the size of the school's faculty over the next few years.

The institute is dedicated to the application, understanding, collection, and risks of data and the development of machine learning and artificial intelligence systems across a range of critical and emerging fields, from neuroscience and precision medicine to climate resilience and sustainability, public sector innovation, and the social sciences and humanities. Its activities will support research activities across the institution.

"Data and artificial intelligence are shaping new horizons of academic research and critical inquiry with profound implications for fields and disciplines across nearly every facet of Johns Hopkins," said Johns Hopkins University President Ronald J. Daniels.

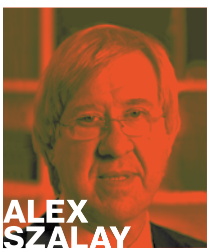
In addition to adding 80 new affiliated faculty appointments in the Whiting School, along with 30 new Bloomberg Distinguished Professors with substantial cross-disciplinary expertise, the effort also will include a state-of-the-art facility on the Homewood campus that will be custom-built to leverage a significant investment in cutting-edge computational resources, advanced technologies, and technical expertise that will serve the entire university community.

"It's not hyperbole to say that data and AI to help us make informed use of that information have vast potential to revolutionize critical areas of discovery and will increasingly shape nearly every aspect of the world we live in," said Ed Schlesinger, the Whiting School's Benjamin T. Rome Dean.

THIS PAGE: JAMES STEINBERG; OPPOSITE PAGE PHOTO OF DEAN SCHLESINGER: MONICA LEIGH.

NEWEST MEMBERS OF THE NATIONAL ACADEMY OF SCIENCES

Two members of the Johns Hopkins Engineering faculty, **JENNIFER ELISSEEFF** and **ALEX SZALAY**, have been elected to the National Academy of Sciences, recognizing their distinguished and continuing achievements in original research.



Elisseeff is a professor of biomedical engineering and interim head of Chemical and Biomolecular Engineering, the Morton Goldberg Professor of Ophthalmology at Johns Hopkins University's School of Medicine, and director of JHU's Translational Tissue Engineering Center. She was previously elected to the National Academy of Engineering and the National Academy of Medicine and is the first Johns Hopkins faculty member to be elected to all three National Academies. (Read more about Elisseeff on p. 20.)

Szalay is a Johns Hopkins Bloomberg Distinguished Professor with appointments in Computer Science and Physics and Astronomy and is the director of the Institute for Data Intensive Engineering and Science. He previously was elected to the American Academy of Arts and Sciences and is a corresponding member of the Hungarian Academy of Sciences.

REWARDING EARLY PROMISE

Two Whiting School assistant professors received National Science Foundation Early CAREER Awards, which recognize early stage scholars with high levels of promise and excellence.

SCOT MILLER, Environmental Health and Engineering, received funding for his project, "Methane Emissions from the US and Canada—Novel Insights from an Expanding Observation Network."

MATHIAS UNBERATH, Computer Science, received funding for his project, "Digital Twins of Surgical Environments for Situational Awareness and Immersive Simulation." Unberath also is a recipient of Google's Research Scholar Program, which funds world-class research conducted by early career professors at institutions around the world. His project is "Assuring Image-Based Surgical Autonomy with Human-in-the-Loop Designs."

ACCELERATING SUSTAINABILITY

YAYUAN LIU, an assistant professor of chemical and biomolecular engineering and researcher at the Ralph O'Connor Sustainable Energy Institute, has been honored by *MIT Technology Review* as one of its 35 Innovators Under 35. Liu is developing carbon-capture methods that are accessible and climate-friendly, not relying on heat.

DISCOVERY FOR DEFENSE

REBECCA SCHULMAN, associate professor of chemical and biomolecular engineering, Kent Gordon Croft Investment Management Faculty Scholar, and fellow at the Hopkins Extreme Materials Institute, was named a 2023 Vannevar Bush Faculty Fellow by the U.S. Department of Defense. The five-year, $3 million individual award, given to 10 people annually, aims to facilitate the progression of fundamental research, encourage collaboration between researchers and national defense experts, and enable investigators to pursue breakthrough discoveries in their fields.

NEUROSCIENCE INNOVATOR

SRI SARMA, associate professor of biomedical engineering and vice dean for graduate education and lifelong learning, received an NIH Outstanding Investigator Award, which provides up to eight years of funding to researchers who are making meaningful contributions to neuroscience. Sarma's goal is to establish novel EEG biomarkers and computational tools that will enable rapid and accurate diagnosis of epilepsy followed by a rapid path to an effective treatment. Her lab is well positioned to address current obstacles in the workflow of diagnosing and treating epilepsy.

A Third Term for Dean Schlesinger

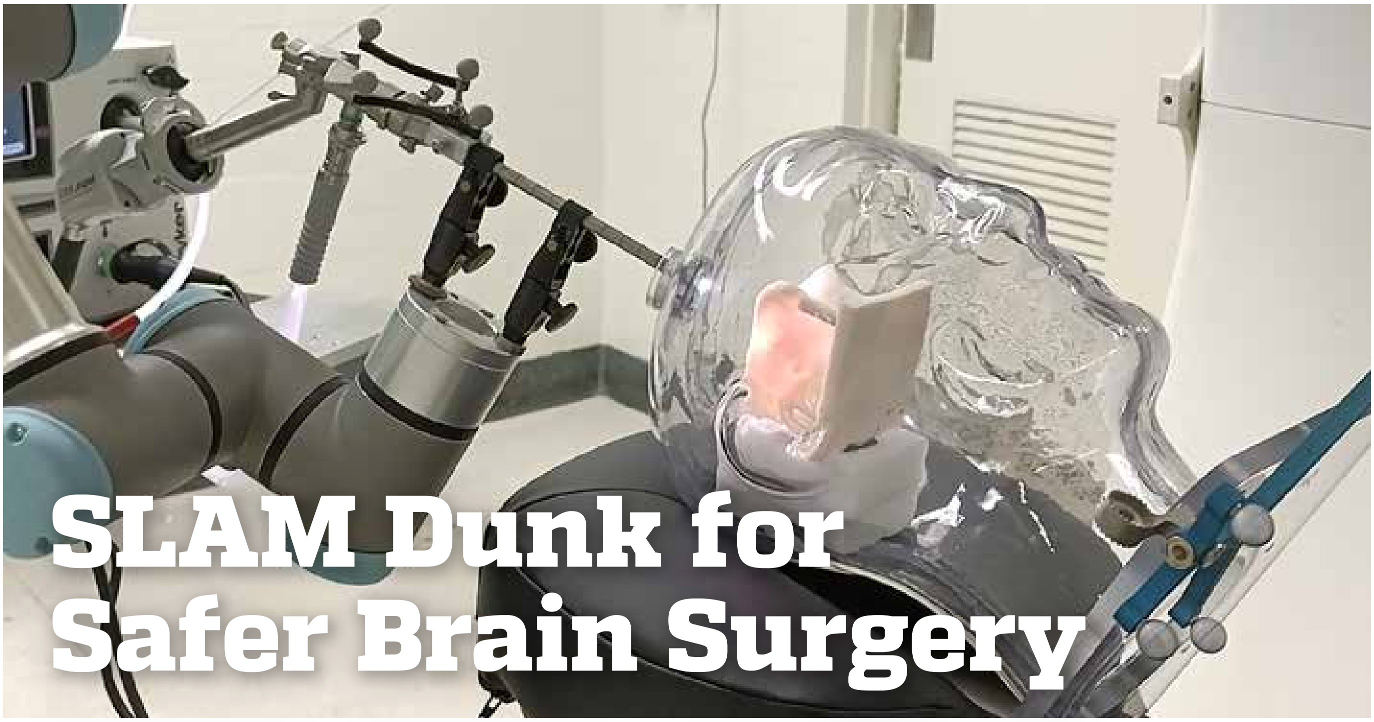
ED SCHLESINGER, WHO HAS SERVED AS DEAN OF THE WHITING SCHOOL OF ENGINEERING SINCE 2014, HAS BEEN appointed to a third term as the school's Benjamin T. Rome dean, through June 30, 2028.

In an announcement to the Johns Hopkins community, President Ronald J. Daniels and then Interim Provost Stephen Gange lauded Schlesinger, saying, "For nearly a decade under Ed's leadership, the Whiting School of Engineering has made tremendous progress in advancing institutional goals and elevating the school's impact both locally and around the globe."

By just about every quantifiable measure, the school has made monumental strides during Schlesinger's tenure. These achievements include doubling the Whiting School's annual research funding and endowment, growing the faculty by approximately 50%, opening state-of-the-art research and educational facilities, advancing in national rankings, and building new partnerships across Johns Hopkins and with peer institutions and industry, as well as launching major new cross-divisional research institutes focused on areas including AI and renewable energy.

Schlesinger also played a leading role in the university's efforts to reimagine the undergraduate experience and curriculum, serving as the co-chair of the Second Commission on Undergraduate Education, or CUE2.

"Given the strong momentum at the Whiting School and exciting new opportunities that lie ahead, we are confident that Ed is the right person to continue to lead the school for years to come," Daniels and Gange wrote.



SLAM Dunk for Safer Brain Surgery

ACCESSING THE BRAIN FOR NEUROSURGERY INVOLVES DRILLING and cutting that can cause deep-brain anatomy to shift or become distorted. This can create discrepancies between preoperative imaging and the actual state of the brain during a procedure.

Current surgical navigation systems may assist in providing live guidance, but typically use pins and clamps to hold a patient's head firmly in place, which carries the risk of complications and can prolong recovery time.

A team of Hopkins researchers at the Imaging for Surgery, Therapy, and Radiology (I-STAR) Labs is working on a less invasive solution that doesn't require additional equipment or expose patients to the extra radiation or long scan times typically associated with live imaging. They have partnered with medical device company Medtronic and the National Institutes of Health to develop a real-time guidance system that uses an endoscope, which is already commonly employed in neurosurgeries. Their work is described in *IEEE Transactions on Medical Robotics and Bionics*.

"Our study demonstrates the superiority of this real-time 3D navigation method over current visualization techniques," says primary author Prasad Vagdargi, a doctoral candidate at the I-STAR Labs who is advised by Jeffrey Siewerdsen, John C. Malone Professor of biomedical engineering with a joint appointment in computer science, and Gregory Hager, the Mandell Bellmore Professor of Computer Science.

The team's surgical guidance method builds on an advanced computer vision technique called simultaneous localization and mapping, or SLAM, which has also been used for navigation in self-driving cars. After calibrating an endoscopic video feed, the team's SLAM algorithm tracks important visual details in each frame and uses those details to determine where the endoscope camera is and how it's positioned. The algorithm then transforms those details into a 3D model of the object: in this case, the inside of a patient's skull. This model is then overlaid with the real-world video feed to visualize targeted structures on-screen in real time.

"Think of it as a dynamic 3D map of a patient's brain that you can use to track and match deep brain deformation with preoperative imaging," Vagdargi says. "Combining this map with an augmented reality overlay on the endoscopic video will help surgeons to visualize targets and critical anatomy well beyond the surface of the brain."

The researchers have coined the term "augmented endoscopy" for this method of live surgical visualization. Through a series of preclinical experiments, they demonstrated that it is more than 16 times faster than previous computer vision techniques while still maintaining submillimeter accuracy.

The team predicts that the improved accuracy afforded by augmented endoscopy may lead to reduced complications, shorter operation times, and therefore increased surgical efficiency—not only in neurosurgeries but also in other endoscopic procedures across medical disciplines.

— JAIMIE PATTERSON

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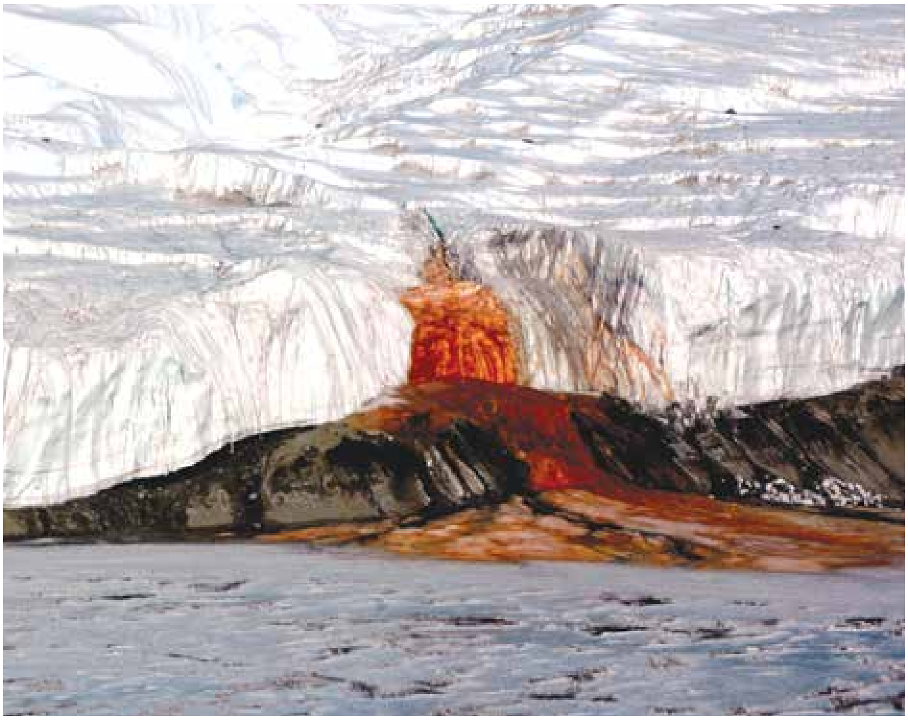

"As soon as I looked at the microscope images, I noticed that there were these little nanospheres and they were iron-rich, and they have lots of different elements in them besides iron—silicon, calcium, aluminum, sodium—and they all varied."

— KEN LIVI

Solving the Mystery of Blood Falls

DURING THE *TERRA NOVA* EXPEDITION TO ANTARCTICA IN 1911, BRITISH GEOLOGIST THOMAS GRIFFITH TAYLOR discovered a mysterious waterfall of what appeared to be blood discharging from beneath the glacier that now bears his name. The water emerges clear but quickly turns crimson—a phenomenon Taylor dubbed "Blood Falls."

Using powerful transmission electron microscopes, Ken Livi, an associate research scientist in the Department of Materials Science and Engineering and director of operations for the Whiting School of Engineering's Materials Characterization and Processing facility, examined samples of Blood Falls water and found an abundance of iron-rich nanospheres that oxidize, turning the water seemingly gory and solving a century-old mystery.

Previously, researchers believed minerals caused the red water, but unlike minerals, nanospheres are not crystalline, so they went undetected.

"As soon as I looked at the microscope images, I noticed that there were these little nanospheres and they were iron-rich, and they have lots of different elements in them besides iron—silicon, calcium, aluminum, sodium—and they all varied," Livi says.

Livi worked on the project with a team that included experts at other institutions, including Jill A. Mikucki, a University of Tennessee microbiologist who has been investigating the Taylor Glacier and Blood Falls for years. Their results appeared in *Frontiers in Astronomy and Space Sciences*.

A prolific Antarctic researcher, Mikucki was part of the team that first identified living organisms in the lake beneath the Taylor Glacier. That team mapped the water's source: an ancient, briny subglacial reservoir containing myriad minerals gathered by the ice in its crawl across the rocks below. The reason for the water's startling gory appearance, though, remained unclear. So Mikucki and astronomer Darby Dyar from Mount Holyoke College sent the samples to Livi at the Materials Characterization and Processing facility.

Livi, a planetary materials expert, says that the ancient, iron- and salt-rich waters under the Taylor Glacier host bacteria strains that may be millions of years old and could inform the search for life on other seemingly inhospitable planets, including Mars.

"There are microorganisms that have been existing for potentially millions of years underneath the saline waters of the Antarctic glacier," he says. "These are ancient waters."

—JACK DARRELL

Y Marks the Spot

THE CHROMOSOME ASSOCIATED WITH MALE DEVELOPMENT—THE LAST MYSTERIOUS PIECE of the human genome—has been fully sequenced by a global team of more than 100 researchers, including those at Johns Hopkins.

The achievement, published in *Nature*, completes the Y chromosome's genetic code and unveils details that could provide a clearer picture of the role the chromosome plays in male-specific development, fertility, and genetically triggered diseases like cancer.

The DNA sequence comprising chromosomes encodes the genes and genetic circuits that guide the development and function of all cells in living organisms. New sequencing technology and bioinformatics algorithms allowed the team to decode the Y chromosome, which has been challenging due to its repetitive molecular patterns.

The team revealed the structures of sperm-regulating gene families and discovered 41 additional genes in the Y chromosome. They also unveiled the structures of genes thought to play significant roles in the growth and functioning of the male reproductive system.

"We completed the wiring diagram for all these genetic switches that get activated via the Y chromosome, many of which are critical to the genetic contributions to male development," said author Michael Schatz, a Bloomberg Distinguished Professor in computer science, biology, and oncology. "We are at a point where scientists can start using this map. We were previously blind to different parts of the genome and different mutations, but now that we can see the whole genome, we hope we can add new insights to the genetics of a lot of different diseases."

The Y chromosome, along with the X chromosome, is often discussed for its role in sexual development. While these chromosomes play a central role, the factors involved in human sexual development are spread across the genome and very complex, giving rise to the array of human sex characteristics found among male, female, and intersex individuals. These categories are not equivalent to gender, which is a social category. Additionally, recent work demonstrates that genes on the Y chromosome contribute to other aspects of human biology, such as cancer risk and severity.

The research was led by the National Human Genome Research Institute, part of the Telomere-to-Telomere consortium that in 2022 unveiled the complete sequence of a human genome.

Other Johns Hopkins authors are Rajiv McCoy, Dylan Taylor, Paul Hook, Winston Timp, Steven Salzberg, Nae-Chyun Chen, Ariel Gershman, Jakob Heinz, Stephen Hwang, Michael Sauria, Alaina Shumate, and Samantha Zarate.

— ROBERTO MOLAR CANDANOSA

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3 Questions

Interview by Lisa Ercolano

The case made headlines earlier this year: An attorney used ChatGPT in legal research on a case, and the AI chatbot cited fake rulings. The judge was not amused. The lawyer said he wasn't aware that large language models could potentially provide inaccurate information.

Joseph Carrigan, a senior security engineer at the Johns Hopkins Information Security Institute, wasn't surprised. Not only may ChatGPT's output "be factually incorrect," he warns, but companies running these models might use your information in other unexpected ways.

1 What are the key security considerations for using large language models (LLMs) safely?

As exemplified by that legal case, you should not be using LLMs to educate yourself about any topic. Also, you need to know what happens to the information you type into the program, even in the form of a question. Though Open AI's end-user license agreement for ChatGPT states they do not use content to improve their model, you are still submitting it. Assume it is stored on their systems. Other LLM providers may use your input to train other models or sell data about you.

2 How can users safeguard their data and ensure privacy?

Always bear in mind that anything you provide to an LLM may be kept by the company hosting it. So don't share any information that you would like to keep confidential—for example, intellectual property. Some users can install their own LLM locally but that requires technical knowledge and computing power not available to many.

3 How can people using LLMs avoid plagiarism and other issues?

It depends on the use case. Students should always generate their own work. Using LLM to generate products for academic coursework may be considered academic dishonesty. Those who generate content professionally are going to have to use LLMs to keep up. The ethics are going to be dictated by the use case. A blogger is probably fine using an LLM to generate content. A commentator writing an opinion piece may not be. Whatever the use case, make sure that you take the time to fact-check the output. You can use a plagiarism scanner if you are specifically concerned about plagiarism.

Shedding Light on Battery Degradation

BATTERIES ARE UBIQUITOUS IN OUR DAILY LIVES, POWERING everything from flashlights and smartphones to computers and electric cars. Yet they often stop working at inopportune moments, and little is known about why they gradually lose their ability to store and deliver energy over time, a process known as degradation.

Yayuan Liu, assistant professor in the Department of Chemical and Biomolecular Engineering, is working to shed light—literally—on why this process happens.

"The higher the voltages the greater the energy batteries can carry, but at that high voltage the battery is really sensitive and prone to degradations," Liu says. "Today people really don't know what the degradation pathway is at high voltages, because a lot of the chemical processes taking place inside the battery as it degrades are very transient in nature. They have lifetimes of [just] seconds to minutes, so that makes it very difficult to look at the root cause."

Liu is taking the concept of fluorescence microscopy—which uses a higher intensity light source than traditional microscopy and is usually applied to biological fields—and adapting it to the study of electrochemical systems.

She notes that despite electrochemical batteries being inorganic and artificially produced, there are striking similarities between the cells in batteries and those in the human body.

"In our body, there is also a generation of transient species like free radicals or heterogeneities, which people study day to day in biology using fluorescence microscopy. I've always been fascinated by the correlations between life science and material science," she says.

Supported by a $600,000, four-year Young Investigator Award from the Arnold and Mabel Beckman Foundation, she hopes to demonstrate the capability of this new imaging tool for electrochemistry research.

She believes fluorescence microscopy is ideal for studying electrochemical systems because it can detect a single molecule emitting visible light and is non-disruptive. "You can observe everything going on in situ, while the battery is operating and without damaging it," she says.

— JONATHAN DEUTSCHMAN

TACO ’bout High Pressure

Many at the Hopkins Extreme Materials Institute look toward the skies to understand forces affecting asteroids and spacecraft. Others focus their attention deep underground.

Understanding sand and rock behavior at high pressure enables scientists to create safer structures, predict responses to planetary impacts, and store CO_2.

Scientists can’t peer directly into the high-pressure environment of the Earth’s crust, but the High-Pressure TriAxial COmpression Instrument, or “HP-TACO,” can help.

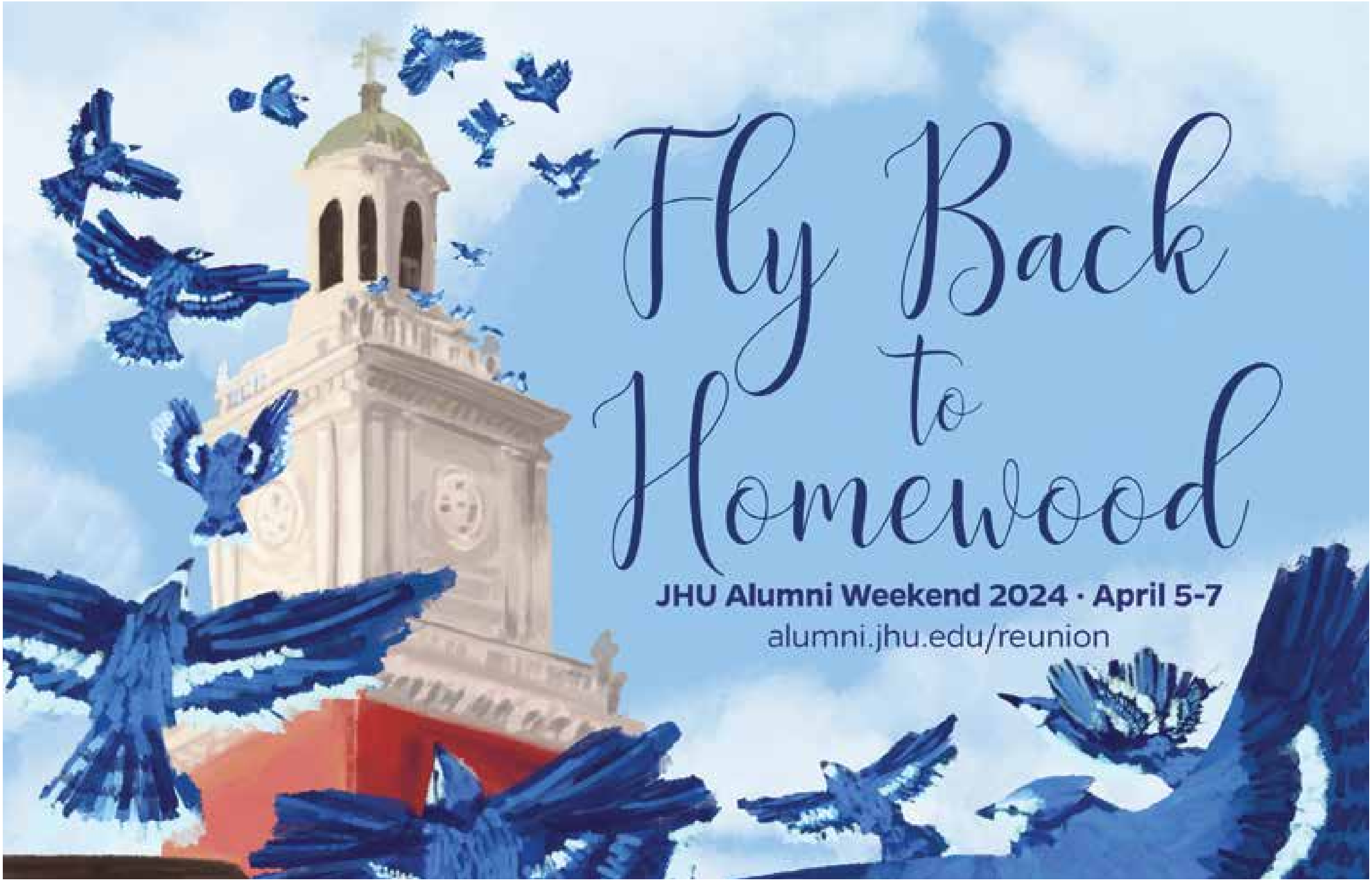
Developed by Ryan Hurley, HEMI fellow and associate professor of mechanical engineering, HP-TACO applies confining pressures of up to 50 megapascals to sands and rocks and compresses them to failure.

“Not only can we emulate the stress states that geomaterials experience within the earth,” says Hurley, “but we can do so while using X-rays to image them in 3D.”

Hurley’s group members have already used HP-TACO to challenge assumptions about sand’s behavior under pressure, and they aim to increase HP-TACO’s capabilities to 200 megapascals—almost double the pressure at the bottom of the Mariana Trench in the North Pacific Ocean.

	Pounds per square inch (PSI)	Multiples of atmospheric pressure	Equivalent ocean depth (meters)
HP-TACO (max. 50 MPa)	7,251	493	4,979
200 MPa	29,008	1,974	19,945

— SARAH PREIS


Fly Back to Homewood
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“Once you go under the waves, without all of these other fancy tools, you have no clue where you are.”

6/21/23, ABC News
Jim Bellingham, Bloomberg Distinguished Professor of exploration robotics, on the loss of the *Titan* submersible

“It’s super fascinating to see how nature managed to create structures so perfectly efficient to take in and hold water.”

4/14/23, *Forbes*
Jochen Mueller, Civil and Systems, on the feathers of the African sandgrouse, which can hold abundant water

“I got the sense that they don’t want to repeat history.”

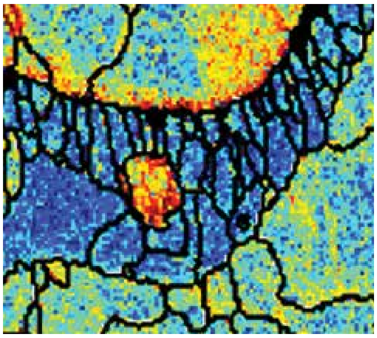
5/5/23, Fox News
Tony Dahbura, Computer Science, on the desire of lawmakers to provide government oversight of AI, as opposed to the free rein afforded to social media platforms over the past 15 years

“These backdoors can be so subtle and clever, and there’s so many ways to do them that you may not even see in the code.”

6/15/23, *Wired*
Matt Green, Computer Science, on how a Chinese firm’s encryption chips got inside the U.S. Navy, NATO, and NAS

“We can probably learn a thing or two from our West Coast friends.”

6/9/23, NBC News
Peter DeCarlo, Environmental Health and Engineering, on New York City’s plans to prepare for the impacts of climate change



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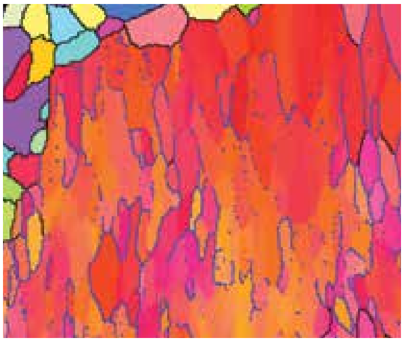
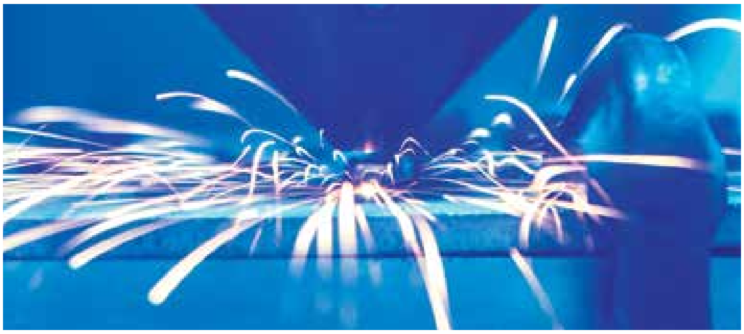
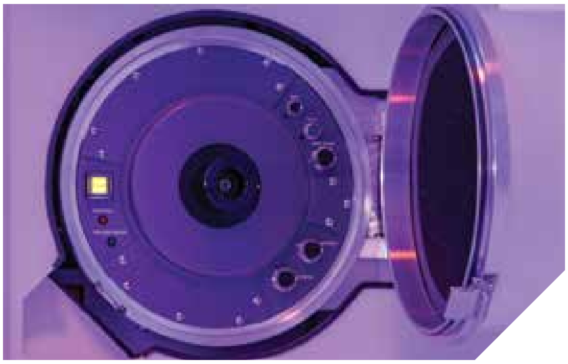
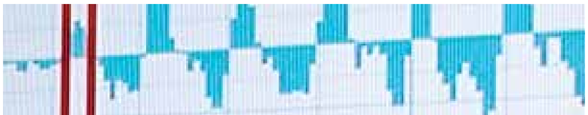
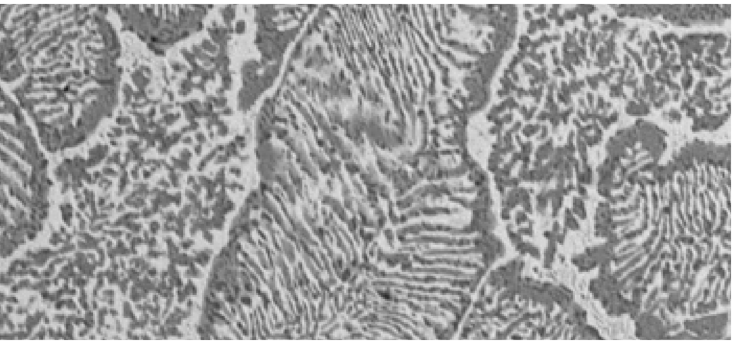






Inside the historic Stieff Silver Building, Johns Hopkins has built the world's top facility for studying the atomic structures of materials. Researchers across the Whiting School are using it to reshape fields from energy to oncology.





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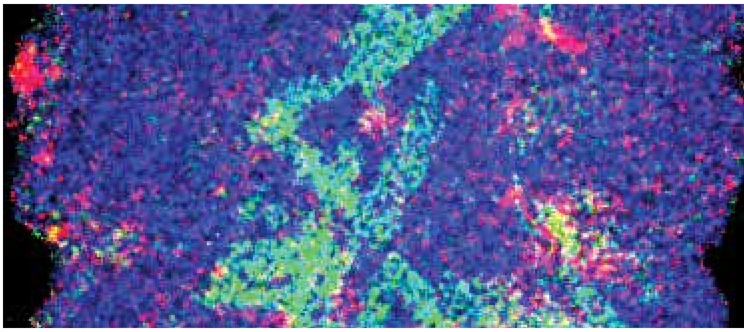
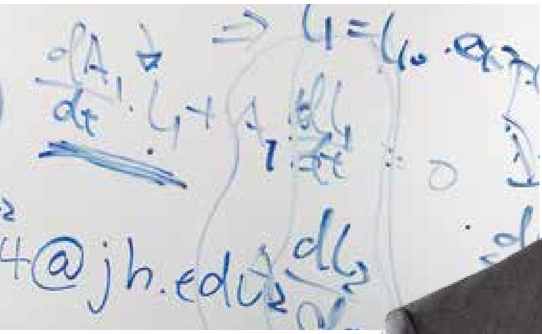
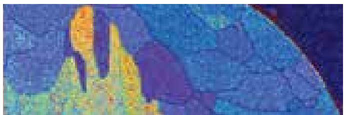


Written By **ANDREW MYERS**
Photos by **CHRIS VACCARO**



Ken Livi and Mitra Taheri



The alligator gar is not an attractive fish. It boasts a long, toothy snout that looks like a cross between a duck's bill and an alligator's grin, by which it earned its name. It can grow to well over six feet and weigh upward of 300 pounds. The alligator gar is a formidable predator, too, but being an apex predator does not mean it lacks natural enemies. And that notion raises the question of why such an ungainly species has survived, virtually unchanged, for nearly 200 million years.

That endurance, say evolutionary biologists, is likely due to the alligator gar's remarkable spade-like scales. They are just plain tough. It was that toughness that brought the Army Corps of Engineers to Ken Livi, a research scientist and director of operations at Johns Hopkins' Materials Characterization and Processing (MCP) facility.

The Corps came calling, hoping he might use the array of world-class imaging tools at Johns Hopkins to reverse engineer why those gar scales are so durable and to possibly turn that knowledge into better armor and shielding, like those that protect spacecraft on reentry.

TOOLS OF THE TRADE

The tools of Livi's world—electron microscopes, spectroscopy, X-ray computed tomography, and others—would allow his team to peer into the very atomic structure of the alligator gar's scales. In all, Livi used no fewer than eight imaging and analysis technologies to examine the scales.

In the end, the team confirmed that the scales comprise an outer layer of ganoine, a hard material akin to tooth enamel, sitting atop a porous-yet-flexible bone-like material. Critically, Livi and team discovered that the two layers are not fused or otherwise glued together, but bound by "rasps" of hydroxyapatite (HAp) extending from the underside of the enamel into the bony structure below. What's more, those rasps are angled toward the outer edge of the scale to create anchoring points, like tent stakes, locking them in place and preventing the material from fracturing into layers, or delaminating, and distributing load when compressed by, say, a predator's bite.

"What makes this material so fascinating is that every part of this simple scale is exquisitely engineered for a purpose," Livi explains. "The rasps angle in and keep the enamel from popping out. Even the arrangement of collagen changes depending upon its location. We couldn't have learned any of this without tools like those at the MCP facility."

NOT YOUR MOM'S MATERIALS CENTER

Such is precisely why, not long after Livi's research was published in 2016, Johns Hopkins began to invest aggressively in the Materials Characterization and Processing facility, putting more than $25 million into this state-of-the-art lab, classroom, and office space. The MCP today boasts a collection of processing and characterization equipment that is, in its entirety, is considered unmatched in the world.

"This may seem like your 'mom's materials center,' but it's not at all," says Mitra Taheri, a professor of materials science and engineering at the Whiting School and director of the Materials Characterization and Processing facility.

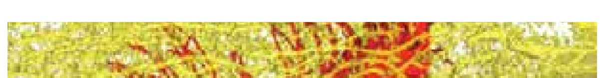
"It's really something built for the next several decades of science," says Taheri, who also heads the Whiting School's Dynamic Characterization Group and serves as a Faculty Fellow of the Hopkins Extreme Materials Institute. "The MCP is a development lab where we're working with microscope and processing manufacturers to remake these tools with embedded artificial intelligence and computing toolsets to be 'thinking machines' for processing autonomy. We're both synthesizing new materials and helping create new tools to produce [those materials]."

The facility is overseen by the School of Engineering, but available to any researchers at Johns Hopkins as well as corporate and government clients eager to lease time on its cutting-edge machinery. All have a vested interest in peering deeper into materials than ever before and creating bespoke materials for next-generation applications. The MCP makes that possible as never before.

A NEW KIND OF 3D PRINTER

Stepping into the 13,000-square-foot Materials Characterization and Processing facility is like stepping into the structure of matter itself. The progressively more powerful microscopes and other tools are arranged along a single corridor. Each successive room plays host to equipment that, incrementally, peers deeper into and controls the structure of new-age materials at the atomic scale—from the micro-computed tomography machines at the front of the hall to the gleaming new scanning transmission electron microscopes at the far end.

The Directed Energy Deposition machine enables researchers to build bespoke alloys layer by layer, offering unprecedented control over materials design.



TRANSFORMING THE MODERN FOUNDRY

- Circulation
- Classroom
- Collaboration
- Dedicated Support
- Existing
- Office
- Research Lab Type I – Most Sensitive
- Research Lab Type II – Sensitive
- Research Lab Type III – Least Sensitive
- Shielding (walls, floor, and ceiling)

One of the first rooms along the way is home to the Directed Energy Deposition machine, a material-creation tool that literally builds bespoke alloys layer by layer. It hosts a ring of vials that can each be filled with different elements that can then be drawn in, little by little, and melted into specific structures by a laser.

"It's a new kind of 3D printer," Taheri says. "The laser 'writes' a new alloy layer by layer but as we're feeding it the raw materials, we can make changes atom by atom. It's like baking as you pour in the batter. It gives us unprecedented control over materials design."

Taheri leads a center-of-excellence partnership with Formalloy, the maker of the DED, to move beyond iterative, additive manufacturing and use ultrafast EDGE computational power and AI/machine learning control for real-time feedback and control of the synthesis process.

Surprisingly, perfection is not the objective, for it is the imperfections, Taheri explains, that determine a material's valuable physical properties, like tensile strength, energy storage, and electromagnetic efficiency. Sometimes those imperfections are the result of "happy accidents" that lead to breakthrough materials. More often, they are the result of careful research and supremely controllable synthesis.

Increasingly, researchers are designing materials on the computer, then coming to the MCP facility to build their creations, explaining the "P" in the MCP moniker—"processing." Taheri, for instance, is using the DED to design next-generation electric vehicle devices and motors under an ARPA-E (Advanced Research Projects Agency-Energy) program for energy-efficient magnets. Similarly, as part of a different global, multi-university team, she is using the DED to develop high-temperature alloys that resist corrosion and oxidation for use in demanding aerospace and marine environments.

The facility also plays host to a multidisciplinary group of Whiting faculty that is contributing to AI-enabled toolsets for bioprocessing, chemical and structural characterization, in operando control, and more.

"Many of the materials we study are built from the atom up. We use these smart machines to build parts and materials right the first time, every time. The hardest part is often getting the raw materials," Taheri says, noting that most nickel is mined in war-torn Ukraine. "We have probably $100,000 in powdered nickel in that vial right there."

Kevin Hemker, the Alonzo B. Decker Chair and professor of mechanical engineering who directs the Johns Hopkins Center for Additive Manufacturing and Architected Materials (JAM^2), knows this territory well. As the name of the center implies, the researchers at JAM^2 are creating architected materials for highly specific, highly demanding applications like space travel, jet engines, new-age armor, and the like.

"In these cases, the question often comes down to how additive manufacturing affects the material at the microstructural and atomic scales," Hemker explains. His research, conducted in collaboration with Jamie Guest, head of the Department of Civil and Systems Engineering, often involves architecting a material on a computer, creating it via DED or laser powder bed fusion (L-PBF), measuring its properties, and, finally, looking into the material, often to the atomic scale, to understand why this particular instantiation of the material has such highly sought-after properties.

In his work, in JAM^2 and at the JHU Applied Physics Laboratory, where he is a senior member of the technical staff, Hemker and his students often take advantage of the MCP's broad range of equipment.

"We use scanning electron microscopes a lot because backscatter mode allows you to see the individual crystallites and map their orientation within the material," he says. "Understanding crystallographic texture explains a lot about why the material behaves the way it does."

Often, his work involves elucidating a material's unusual properties and then, and only then, going to MCP to figure out how and why the material behaves the way it does. One recent example, a collaboration with researchers at APL, involved the additive manufacturing of metal-matrix composites.

M. Raju, MCP's assistant research scientist for X-ray techniques and a postdoctoral fellow in Physics and Astronomy, inserts dried mitochondria to be scanned in the micro-CT, a tool that provides non-destructive, high-resolution 3D images of materials.

"The APL researchers discovered that the additively manufactured metal-matrix composite exhibited both enhanced mechanical properties and environmental resistance," Hemker explained, "and we were able to show them how the atoms rearranged themselves during the additive processing, which helped explain why the material has the properties it does."

IN EXTREMIS

At the next stop, a team of researchers huddles around a computer terminal next to a gray box the size of a large armoire. On the computer screen is a 3D image of a

round mass that that looks a bit like a ball of falafel. It is, in reality, a digital image of cemented sand developed for the Hopkins Extreme Materials Institute.

The lead researcher at the computer this day is Ryan Hurley, an associate professor of mechanical engineering and Faculty Fellow at HEMI. The machine in the gray box is a micro-CT—microcomputed tomography—one of the key technologies Livi used to image the garfish scale. Micro-CT uses X-rays to create three-dimensional digital images of the material in question.

Nearby, Hurley's real-world sample sits inside the micro-CT within a custom-built device that simulates an extreme environment. Hurley can dial up the pressure, tension, and other stresses while imaging his sample in three dimensions in real time, analyzing the points of failure using computer algorithms.

Such cemented sands can be found everywhere on the surface of the Earth and on planetary bodies throughout the solar system. The way that they respond to mechanical loading is critical for such disparate needs as constructing buildings or predicting the effect of an asteroid impact. Hurley takes what he learns at MCP back to the lab to fine-tune numerical models to accurately predict how the materials will behave in the real world.

"Micro-CT lets us look inside a 3D sample and actually see how it's breaking down at the microstructural level," Hurley says.

The transmission electron microscope (TEM) uses an electron beam to visualize specimens and generates highly magnified cross-sections of materials.

THE 'ZERO' ENVIRONMENT

The next room includes the first piece of equipment in the facility to resemble a traditional microscope, albeit at tabletop scale—an entire tabletop, that is. What would traditionally be an eyepiece plays host to a digital camera transmitting imagery to an observation room nearby. This is what is known as a focused ion beam-scanning electron microscope, a FIB-SEM. It operates on the same principle as a traditional light microscope, Taheri says, but employs a beam of ions to slice into a sample in ultrathin layers while a column of electrons illuminates each cross-section for high-resolution imaging.

Electron microscopes, like the transmission electron microscope (TEM) in the next room along the hall, have an electron beam that is far more sensitive than any light-based microscope, Taheri says, but are also much more "finicky." With a TEM, the slightest vibration (a footstep or the slightest sound) can imperil results.

"We need a zero environment—no vibrations, no interference. With some of these more sensitive transmission electron microscopes, the samples are so small a single breath—'huh,' just like that—and it's curtains," Taheri says, making a slight puff for dramatic effect.

A key decision in creating a zero environment was Johns Hopkins' choice to forego a new building and instead renovate the Stieff Silver Building at the southwest corner of campus. While the building's legacy as a precious metal foundry provided a metaphorical hook—Taheri refers to the facility as "transforming the modern foundry"—something more was at play. The Stieff building rests directly on bedrock, an unmatched foundation for the MCP's ultrasensitive machines.

All rooms are individually isolated to further dampen vibration. Inside, the rooms look more like recording studios than labs. The hospital-white walls are canted slightly so as not to meet at right angles, and each is peppered with odd-angled acoustic panels to further deaden sound. Many rooms are fitted with large cooling panels that hold temperatures within tight specifications to eliminate thermal expansion and contraction that can likewise imperil results. Last but certainly not least, the most sensitive electron microscopes are also prone to electromagnetic disruption and must be shrouded in room-within-a-room metal superstructures that jam interference.

Tarunika Ramprasad and Ken Livi, research scientists in Materials Science and Engineering, in the FIB-SEM (focused ion beam-scanning electron microscope) lab.

LIVING ON THE EDGE

The full import of such meticulous dampening becomes apparent a minute later as Taheri walks out of the lab and down a door into the u-shaped hallway surrounding the FIBSEM lab, where the ear is deluged by noise. It is the fever-pitch of fans and pumps straining to cool the computer equipment churning through the vast data the microscopes are spitting out.

These are next-generation EDGE computers. They are so fast that proximity to the source is a key factor in their performance. They are literally at the "edge" of the labs they serve. Taheri notes that some of the microscopes are capturing 20,000 high-resolution frames per second.

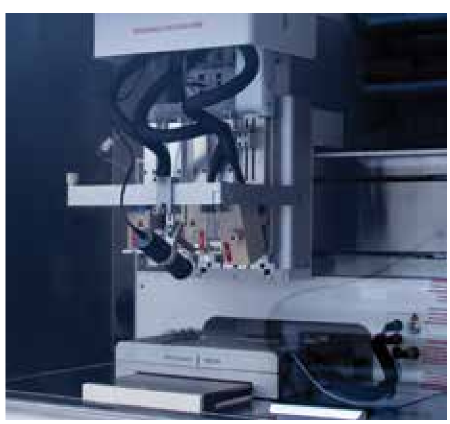
"This is an exciting capability and demands this type of next-generation computing as we are bringing in data so rapidly that we must develop new computing algorithms and devices to manage and process it all," Taheri says. "Levering EDGE computing will get us closer to our vision of autonomous labs by allowing computers to make rapid decisions about an experiment as it's happening."

Likewise, the many terabytes of data flowing out each second means heat—a lot of heat. All that firepower must be cooled to function properly.

"You're looking at the sausage-making machinery of the MCP," Taheri shouts above the din of fans. Meanwhile, in the lab, just few feet away through the wall, people talk in whispers.

AN UNPRECEDENTED LEVEL

Next, Taheri leads to a room that contains the newest microscope at the MCP, the JEOL Grand ARM II (JEM-ARM300F2). It is currently the only one of its kind in the United States as it was acquired through a cost-sharing Center of Excellence partnership with the manufacturer Japanese Electron Optics Laboratory and its subsidiary, IDES. The ARM II acts not only as a tool for the community of users looking into interesting materials such as quantum, structural, biological systems, but also as a landscape for the development of intelligent microscopy and novel characterization techniques that are both smart and ultrafast. The ARM II's detectors and systems allow researchers to see and understand materials beyond anything that came before.



The RegenHU bioprinter can print synthetic biological tissue and is enabling new understanding of how a tissue's mechanical properties may impact the effectiveness of therapies.

"The ARM II boasts subatomic resolution," Taheri says proudly. "This is a Lamborghini compared to the Camry I learned on in graduate school."

The scale bar on images from the Grand ARM II are often less than half a nanometer—two-billionths of a meter. The microscope showcases the world's best sensing and imaging tools, that see materials smaller than an atom and can watch them move at rates orders of magnitude less than a second.

"This is the birthplace of new materials for computing, medicine, and more. This is the electron gun. And the specimen goes here," she notes, pointing to the maze of tubes and wires that looks more like science fiction than a microscope of old.

The electron beam is fully controllable and able to make real-time decisions about how the beam is interacting with a sample to precisely calibrate energy and correct lens aberrations to achieve maximum resolution.

"We have a paper in transit with the first evidence of our ability to dose control to look at living tissues without harming them, which is a major advance in understanding biological systems that usually require being frozen in order to be imaged," she says of the Grand ARM II's exceptional control.

WALKING THE WALK

As we round the corner at the far end of the main hallway, the MCP facility has yet one more surprise in store. It is a bioprinter: a machine that can print synthetic biological tissues.

Yun Chen, an assistant professor of mechanical engineering and a researcher in the Institute for NanoBioTechnology, runs the Mechanical Engineering of Wet-materials Laboratory, the MEOW Lab. Her specialty is applying the mechanical analysis of intercellular forces to diagnose and treat conditions like cancer and heart disease.

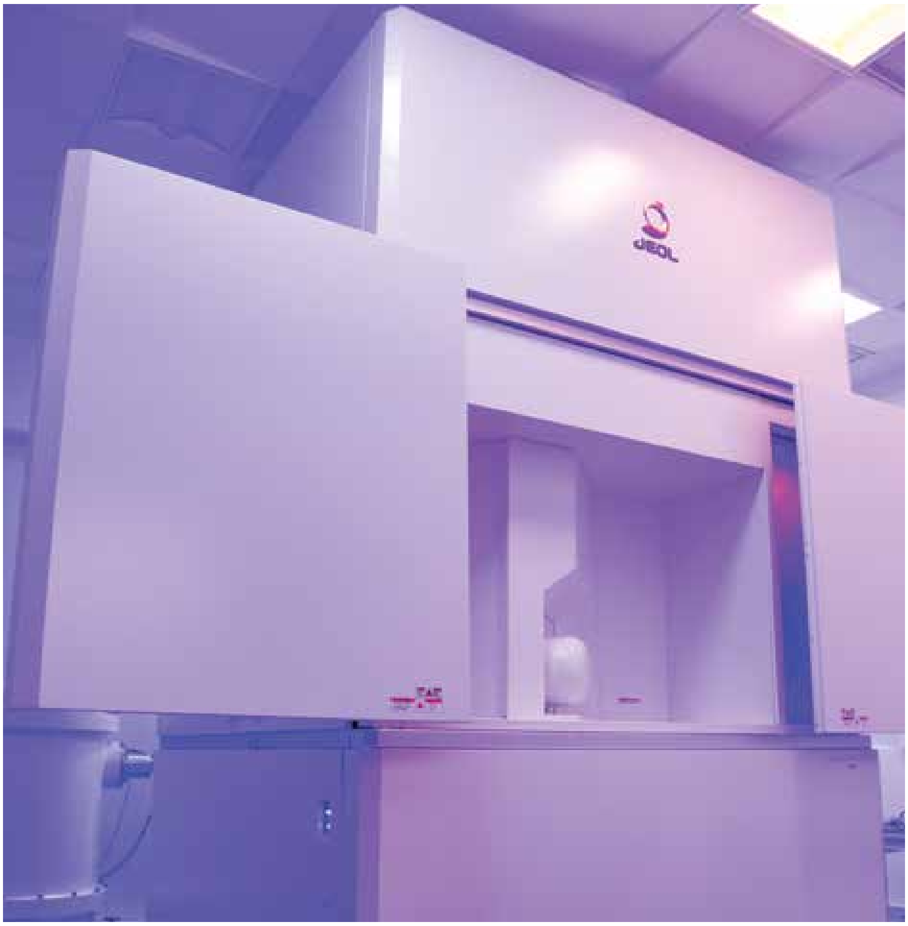
It turns out that human cells adapt and adjust behaviors to the rigidity of their surroundings. Cancer cells will even respond differently to chemotherapies depending on the stiffness of their environment. Therefore, it requires different types of drugs and often varying dosages to kill cancer cells invading soft brain tissue versus hard bone. To more effectively screen new drugs and dosages, Chen employs the MCP's bioprinter to fabricate synthetic tissues that have softness comparable to that of the targeted human tissue.

"The bioprinter in the MCP is capable of tuning the softness of the printed synthetic tissues to mimic any type of human tissue—brain, muscle, or bone," Chen explains.

But cancer is not Chen's only target. The bioprinter can print cardiac tissues that beat just like a real human heart. Chen's group has published three highly cited papers demonstrating the potential of bioprinted cardiac tissues.

Already, Chen notes, "bioprinted cardiac cells can even be implanted into the damaged tissues of patients suffering heart failure."

The key for both cancer and heart disease is to get the cellular composition and the rigidity of the fabricated tissue as close to the human tissue as possible.



The MCP's JEOL Grand ARM (Atomic Resolution analytical Microscope) II offers subatomic resolution, enabling researchers to explore matter at the scale of less than 60 trillionths of a meter.

Empowered with a bioprinter that can tune the mechanical properties of fabricated tissues to those of real tissues, Chen is now turning her sights on clinical research and treatment strategies to diseases beyond cancer and heart disease.

"The takeaway from all this is that life is as much a mechanical process as a biochemical process. When diseases occur, biomechanics are often at play," Chen says. "We can use that knowledge to understand and approach diseases in new ways. The MCP's bioprinter plays a key role in helping us do that."

THE BIG PICTURE

Tour complete, Taheri pauses a moment amid the handsome exposed brick of the Stieff foundry to consider all that is within its walls. With such a slate of impressive machinery—her "kids" as she calls them—Taheri says the next natural step for the MCP facility is something she calls "collaborative autonomy."

"We want the 'kids' to play nicely together. We want these incredible, individual machines to think collaboratively, to move from automation to autonomy. The MCP is a large-scale effort to move Hopkins into the next great era of materials science and artificial intelligence," Taheri says, pivoting back toward her office. ■

NNOVATION at the Crossroads'

Biomedical engineer Jennifer Elisseeff is known for asking bold questions and pursuing seemingly "outlandish" ideas that pay off big. Her latest cross-disciplinary pursuit? Unlocking the mysteries of aging.

Written by CHRISTINA HERNANDEZ SHERWOOD
Photography by HOWARD KORN

Senescent cells are known to accumulate in our bodies as we get older. Though they have stopped multiplying, they remain alive, releasing chemicals that can cause inflammation.

Jennifer Elisseeff believes these cells might hold the key to unlocking a crucial component of the aging process. To find out how, she is looking to an unlikely culprit: fibroids. Largely benign, these muscular tumors grow in the uterus and cause pain and bleeding. Fibroids are packed with senescent cells.

"If you can understand what's going wrong, you can start blocking it," says Elisseeff, who is collaborating with researchers in the Department of Gynecology and Obstetrics at Johns Hopkins Medicine.

The project—one in a series of multidisciplinary efforts meant to chip away at the mechanisms of aging and find therapies to help our bodies regenerate—is emblematic of Elisseeff's penchant to ask bold questions and forge collaborations across a disparate array of fields.

A biomedical engineering professor at Johns Hopkins for 22 years, Elisseeff was recently named interim director of the Department of Chemical and Biomolecular Engineering. She is also the Morton Goldberg Professor of Ophthalmology.

Notably, she is the university's only faculty member to be elected to all three national academies: the National Academy of Sciences (2023), the National Academy of Engineering (2018), and the National Academy of Medicine (2018).

After first using her biomaterials expertise to develop regenerative therapies and launch two successful startup companies, Elisseeff took a rare mid-career pivot into a complex field outside her specialty: immunology.

Today she is a leading expert on regenerative immunology—a burgeoning area of research that aims to harness the power of the immune system to heal the body—and her innovative collaborations with experts in cancer immunotherapy and computational biology, among other fields, have wide-ranging implications for tissue regeneration, cancer therapies, and diseases of aging.

"Jennifer is not afraid to come up with an idea that could very well be looked at as outlandish," says Drew Pardoll, director of the Bloomberg-Kimmel Institute for Cancer Immunotherapy and oncology professor at Johns Hopkins Medicine. "Some of those ideas develop momentum and, all of a sudden, outlandish becomes transformative."

The Immune System's 'First Responder'

Elisseeff has been working on senescent cells for more than six years. In a seminal paper published in 2017 in *Nature Medicine*, she showed that eliminating senescent cells from an arthritic joint reduced pain and increased cartilage development. Her lab is now part of the NIH Common Fund Cellular Senescence Network, a collaborative program uniting cellular senescence researchers to study and publish public data on these important cells.

Her interest in senescent cells grew out of her fascination with the immune system. Senescent cells signal that the immune system has been activated, which occurs during tissue development and repair, as well as during harmful chronic inflammation.

She explains that while we most often think about the immune system in the context of vaccine efficiency or fighting infections, part of its job is to recycle cells that are no longer functioning as they should. The immune system also plays a role in the aging process. "The immune system is a first responder to tissue damage," Elisseeff says, which has led her to ask: "How does aging change the immune environment and impact our ability to repair tissues?"

In partnership with bioinformatics colleagues at Johns Hopkins Medicine, Elisseeff has developed computational techniques to study how the immune system communicates—in young animals versus older animals—and how it changes and inhibits tissue repair. The goal, she says, is a new strategy for developing therapeutic targets for the illnesses of aging, such as neurodegenerative disease and frailty. This new strategy, she explains, will need to consider immune factors, such as diet, microbiome, history of infections, and comorbidities.

"[Typically] those factors aren't part of the design process when you're making new therapies for people," she says. "How many therapies failed because those factors weren't considered?"

Elisseeff was the first engineer to collaborate with the Bloomberg-Kimmel Institute for Cancer Immunotherapy, and she has since recruited other biomedical engineers to join her efforts there. "Hopkins has amazing immunologists," she says, "and not only basic science immunology, but also translational immunology, which is super exciting."

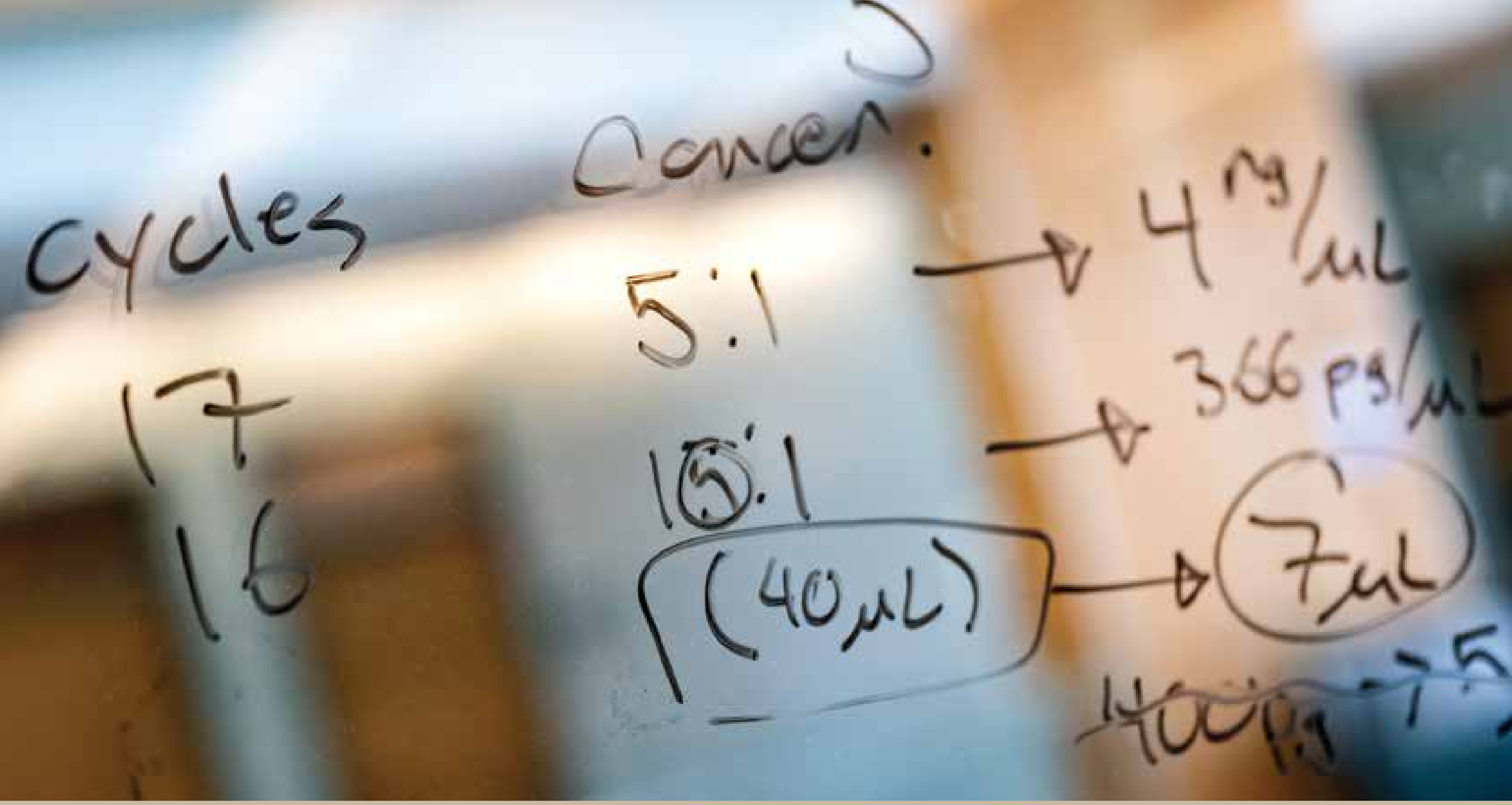
Her current focus involves leading the institute's program to engineer the tumor microenvironment, the complex ecosystem of cells, blood vessels, and other components that surround a tumor. She found that senescent cells play a role in these tumor microenvironments: When noncancer cells in a tumor were senescing, they could give the tumor a "senescence signature" that correlated with poor immunotherapy outcomes for cancer patients.

"She's connecting dots that no other scientist has connected," Pardoll says. "This is really very novel."

Elisseeff's senescence work has helped the researchers at the Bloomberg-Kimmel Institute to draw a clearer picture of the tumor microenvironment. "It had a major impact on our research into how a tumor microenvironment is organized, which, in turn, has broadened our

"Jennifer is not afraid to come up with an idea that could very well be looked at as outlandish. Some of those ideas develop momentum and, all of a sudden, outlandish becomes transformative."

—**Drew Pardoll**, *director of the Bloomberg-Kimmel Institute for Cancer Immunotherapy*



thinking about how to therapeutically target these cells," says Pardoll.

As Elisseeff learns more about senescent cells, and the other cells within tumors, she is aiming to engineer the ideal tumor microenvironment to make cancer immunotherapy treatments more effective—and make tumors more susceptible to those treatments.

"What environment promotes tumor growth and more resistance to therapies," she says, "versus inhibiting tumor growth and increasing immunotherapy response?"

Improving Lives

When Elisseeff was a high schooler in the early 1990s, she could frequently be found in her father's laboratory in the Department of Ocean and Mechanical Engineering at Florida Atlantic University in Boca Raton. A lover of nature with a penchant for science fairs, she was soon conducting her own basic research. In one particularly prescient example, the young Elisseeff studied how microbes impacted the chemical process on metal surfaces.

Even from a young age, she was intrigued by the collision of the natural and the synthetic. "Innovation happens at the crossroads," she says.

On the recommendation of a favorite science teacher, Elisseeff attended Carnegie Mellon University, settling on an undergraduate degree in chemistry. While studying polymer chemistry, Elisseeff was introduced to the idea of combining polymers with biology—that is, biomaterials—bringing her closer to the medical field. Elisseeff pursued her PhD in biomedical engineering at the Harvard–MIT Division of Health Sciences and Technology, attended two years of medical school, and completed a postdoctoral program at the National Institutes of Health.

She joined Hopkins' Department of Biomedical Engineering in 2001. "What is unique about biomedical engineering here is how it's embedded in medicine," she says. "I was attracted by the ability to bridge the different schools and start a new collaboration with physicians out of the blue, whether it be a cornea surgeon or a gynecologist studying fibroids or a cancer researcher."

Her initial focus was engineering biomaterials, synthetic systems that could heal tissue wounds. She developed adhesive and biomaterial technologies to treat arthritis, restoring cartilage that had deteriorated in patients' aching knees. The work led to her first startup, a company called Cartilix Inc. that was founded in 2004 and acquired by Biomet Inc. five years later. By then, Elisseeff's interests had expanded into soft tissue regeneration, and she founded two more startups to translate her work.

A proponent of translating academic research into treatments for patients, Elisseeff recruited Jordan Green, the Herschel L. Seder Professor in Biomedical Engineering, to help establish the Translational Tissue Engineering Center (TTEC), a collaboration with the Wilmer Eye Institute, in 2010.

"Jennifer cares about the big picture," says Green, who is now the department's vice chair for research and translation and TTEC's associate director. "It's not just the science, but how the science can impact society."

Following Elisseeff's lead, Green became involved in the work of the ophthalmologists at Wilmer—a partnership he hadn't expected. "She likes to bring different kinds of people together," he says, noting that the TTEC floor is often filled with a mix of clinicians, medical students, residents, and researchers working together. "That environment can more easily lead to translational outcomes."

Green has since founded two startups: Asclepix Therapeutics, which develops a peptide drug to treat wet age-related macular degeneration, and Cove Therapeutics, which develops nonviral gene therapy in the eye. "If it wasn't for Jennifer's leadership, I don't think those would have happened," he says. "It resonates with me that the research we do can lead to improvement to the quality of life for people who need help."

It was the process of translating technologies to the clinical setting that made Elisseeff in 2013 begin to take an interest in the immune system—our body's complex web of defenses—which she until then knew little about.

"We developed these therapies, but if you put them in an inflammatory environment, they're not going to work," she says. Without any formal immunology training, Elisseeff came to the conclusion that the immune system was key to successful regeneration. "That was a real clincher," she says. "I had to learn some immunology."

So, in an exceedingly rare move for an already-renowned researcher a dozen years into her career, Elisseeff embarked on a semester-long sabbatical at the Swiss Federal Institute of Technology in Lausanne for an intensive immersion into the world of immunology.

Mentoring Women in Science

When she returned a few months later, Elisseeff connected with Kaitlyn Sadtler, a new graduate student with an interest in immunology who wanted to do a rotation in her lab. "Having had zero experience in bioengineering, I had no idea how big of a deal she was," Sadtler says, laughing.

Soon, Sadtler had joined Elisseeff's lab. Elisseeff, along with Pardoll, advised Sadtler on her PhD thesis. The resulting paper, a transformative work published in *Science* in 2016, showed that a specific type of T cell, previously known to combat parasitic microbial infections, was also central to wound healing.

Now a tenure-track investigator at the National Institutes of Health and chief of the Section on Immunoengineering, Sadtler says Elisseeff remains the only female principal investigator she has ever worked under. Elisseeff's example as a role model—she once bought her mentee dinner when the graduate student looked wan after a long day in the lab—inspired Sadtler to mentor other women in science. "It's hard to be what you can't see," she says.

Elisseeff considers her mentorship of women engineers one of her greatest accomplishments to date. "I've trained a lot of [women] students who are now faculty," she says. "When you look at gender diversity in [engineering] departments, there's usually not a great balance. My contribution of training women who now are in faculty positions around the world doing great work is important for the field."

The Next 'Crazy Challenge'

Elisseeff's lab work isn't her only race against time. She also competes in short-distance triathlons, races that include swimming, biking, and running segments, as part of her personal quest to age healthfully.

"It's a sport where you have some diversity of different activities," she says. "I enjoy mixing it up."

When she's not listening to music to stave off the tedium of the long, slow runs mandated by her triathlon training program ("It's boring trying to be disciplined to go slower," she says), Elisseeff sometimes finds herself musing on the engineering problems she's trying to solve in the lab. Her next "crazy challenge" stems from her fibrosis work.

Elisseeff's lab has data to suggest that T cells—adaptive immune cells known to combat outside invaders, such as germs and disease—might be recognizing fibrosis and perhaps, by extension, other types of tissue damage. If that's true, it goes against basic immunology dogma because T cells aren't supposed to be self-reactive: That's considered an autoimmune disease. The notion is "a little bit controversial in some sense," Elisseeff says.

"The adaptive immune system isn't recognized as having a big role in tissue repair or a lack of repair," she says. "This is a new way of looking at the role of the immune system in tissue repair that's just very different." But if Elisseeff can prove that T cells are recognizing fibrosis—which is no small feat—the finding could open up a huge new avenue of research into how T cells contribute to aging.

"I feel like I haven't made my most important contribution yet," she says. ■

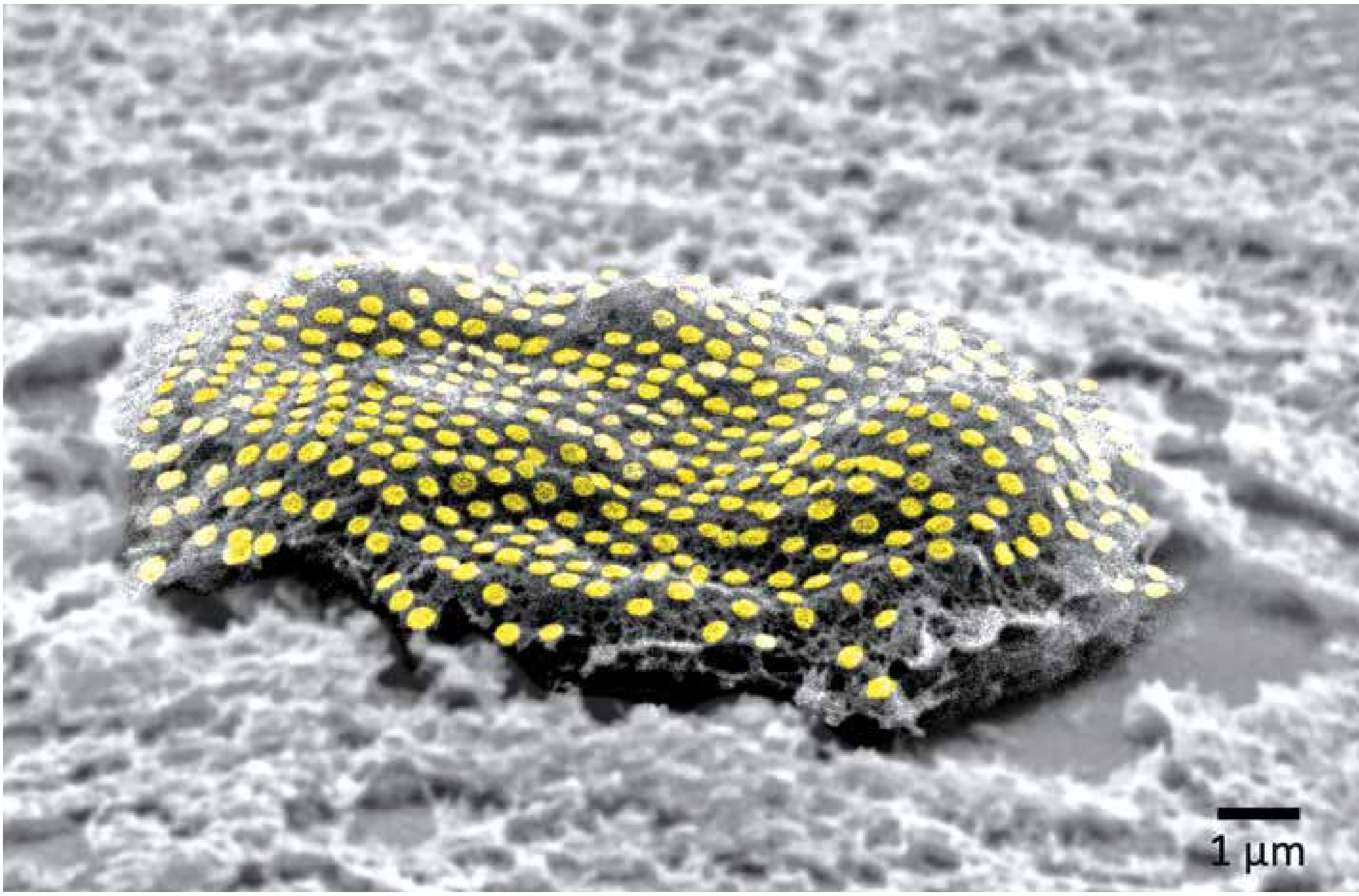
"Jennifer cares about the big picture. It's not just the science, but how the science can impact society."

—**Jordan Green**, *vice chair for research and translation for the Department of Biomedical Engineering*

HIDDEN REALMS

BY JOHNS HOPKINS STAFF
IMAGES COURTESY OF FEATURED RESEARCHERS

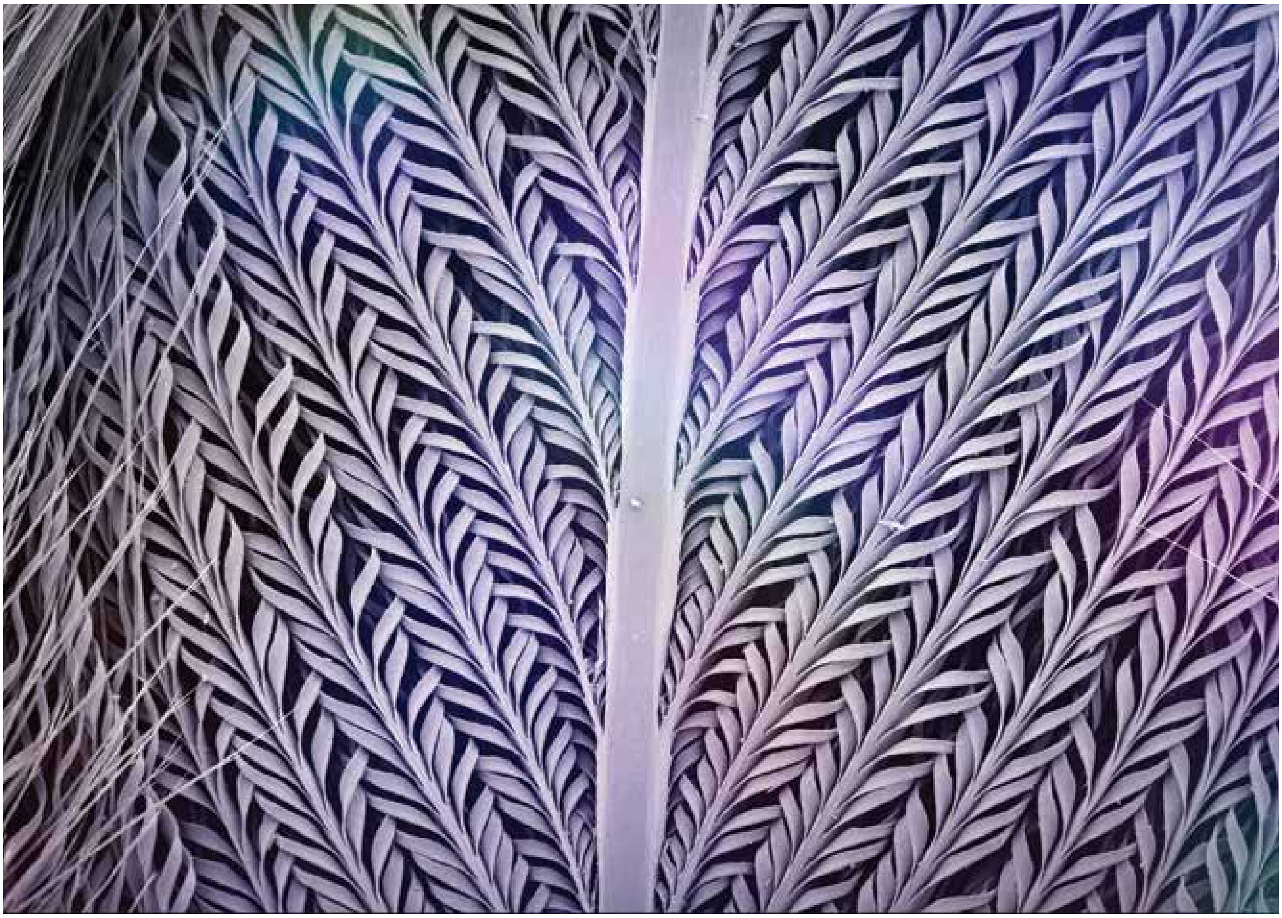
They say that beauty lies in the eye of the beholder. But sometimes it's too small, too complex, or even too fast for the naked eye to appreciate or comprehend. Using tools that range from powerful electron microscopy to computer simulations and 3D printers, Johns Hopkins engineers are uncovering the unseen and, in the process, transforming science into art.



TINY TATS

David Gracias

These gold dots, hundreds of times smaller than the head of a pin, may signal the future of disease diagnosis and treatment. Developed by David Gracias, a professor of chemical and biomolecular engineering, the dots are lithographically patterned tattoos that contain model patterns of optical elements and electronics and can be stuck to individual live cells using a molecular glue. Gracias' goal is to be able to remotely track the health of isolated cells using biosensor technologies. "We would like to have sensors to remotely monitor and control the state of individual cells and the environment surrounding those cells in real time," Gracias says. "If we had technologies to track the health of isolated cells, we could maybe diagnose and treat diseases much earlier and not wait until the entire organ is damaged."



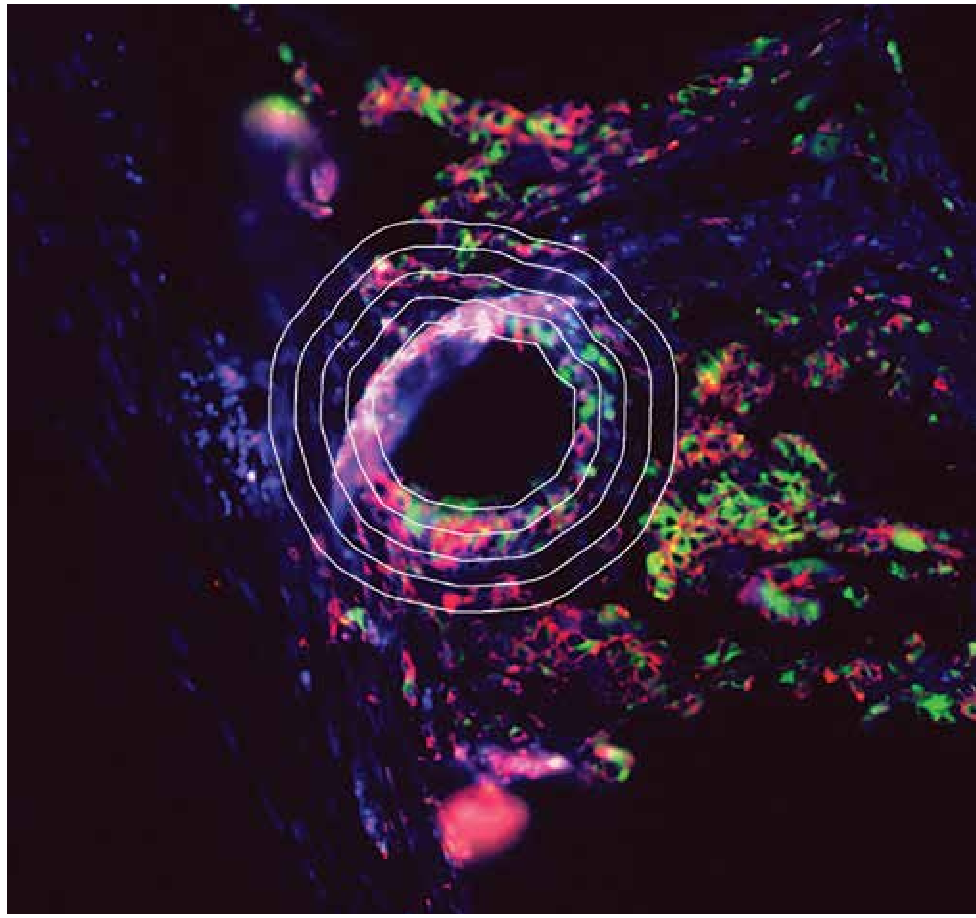
Desert Sandgrouse Rachis 50x with scale_Glow | 500 μm

BIRDS OF A FEATHER

Jochen Mueller

Desert Sandgrouse Rachis 75x with scale_BW streets | 200 μm

Using high-resolution microscopes and 3D technology, Jochen Mueller, an assistant professor of civil and systems engineering, and researchers at Massachusetts Institute of Technology, have captured an unprecedented view of feathers from a male desert-dwelling sandgrouse, a bird known for its ability to carry water—up to 15% of its body weight—in its belly feathers. High-tech imaging technologies enabled the team to examine the feathers' microstructure. Looking closely at the shafts, each just a fraction of the width of a human hair, and the even tinier individual barbules, they identified components in the feathers' structure that are optimized to hold and retain water. "That's what excited us, to see that level of detail," Mueller says. This knowledge could help inform the design of new materials for absorbing, retaining, and releasing liquids.



DEALING WITH REJECTION

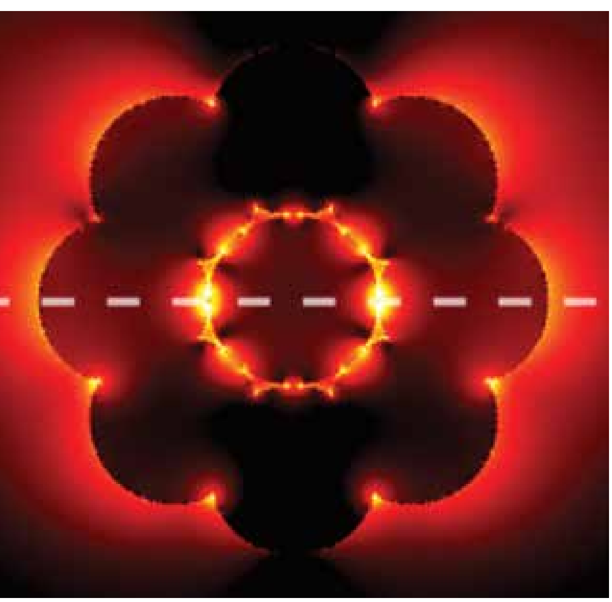
Joshua Doloff

These swirls of bright colors, images of tissue stained with fluorescent labels, may herald a breakthrough in preventing medical implant rejection. Joshua Doloff, an assistant professor of biomedical engineering, discovered an advanced "humanized" mouse model that he is using to investigate why scar tissue forms around an implanted device, a process known as fibrosis. Doloff and his team inserted different material implants in the genetically modified mice to see how and where immune cells would gather around the implants over time. Using fluorescent microscopy to view tissues that had been stained beforehand with fluorescent labels, the researchers were able to use a multiplexed antibody array to detect the location (as a function of distance away from the implant surface) of human immune cell players, revealing events in the early development and progression of fibrosis.

CAN YOU SEE ME NOW?

Vishal Patel and Nithin Gopalakrishnan Nair

One obstacle to ensuring the accuracy of facial verification is that the software simply doesn't work well in low-light or nighttime conditions when images must be taken using thermal cameras. But Vishal Patel, an associate professor of electrical and computer engineering, and Nithin Gopalakrishnan Nair, a PhD student in electrical and computer engineering, have devised a way to improve facial recognition in these challenging situations using their denoising diffusion probabilistic model, which can convert "noisy" images created with thermal cameras into clear, photo-like ones. Using a diffusion process to train their model, they showed the system pairs of images—one, a normal photo, and the other, a thermal image of the same scene. By comparing the images, the system learned to understand the "relationships" between regular photos and thermal images, learning how features such as faces can be transformed from the thermal to the visible domain.



532 nm

SHINE BRIGHT LIKE A NANODIAMOND

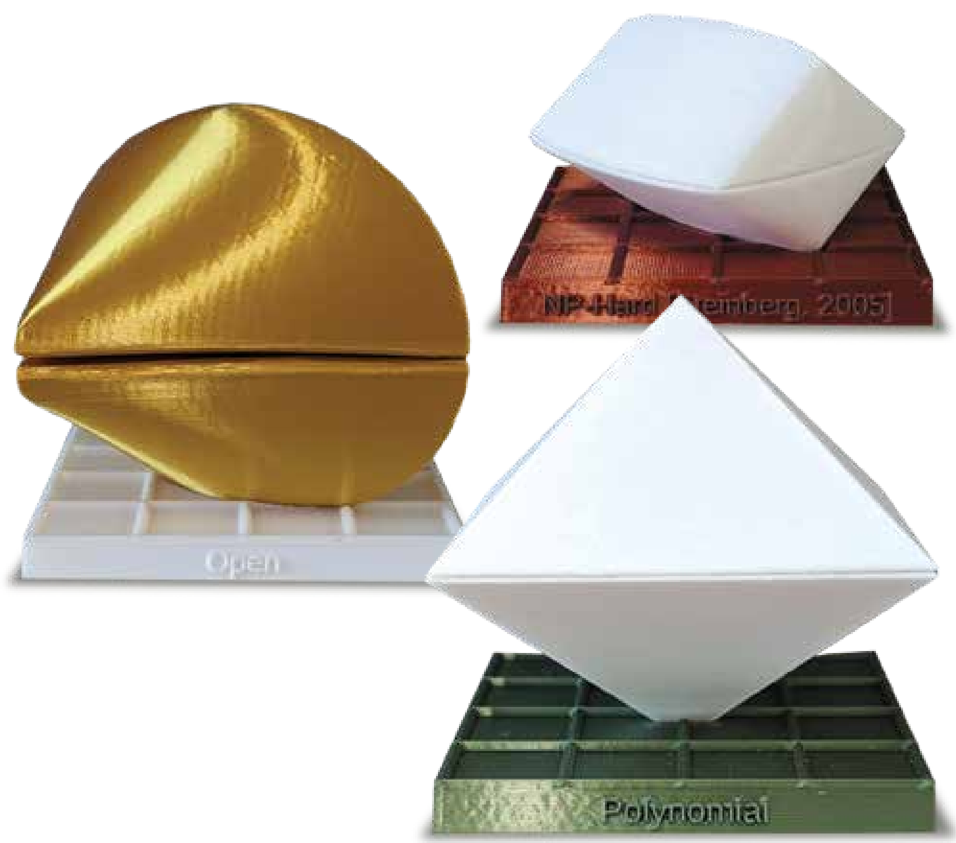
Ishan Barman

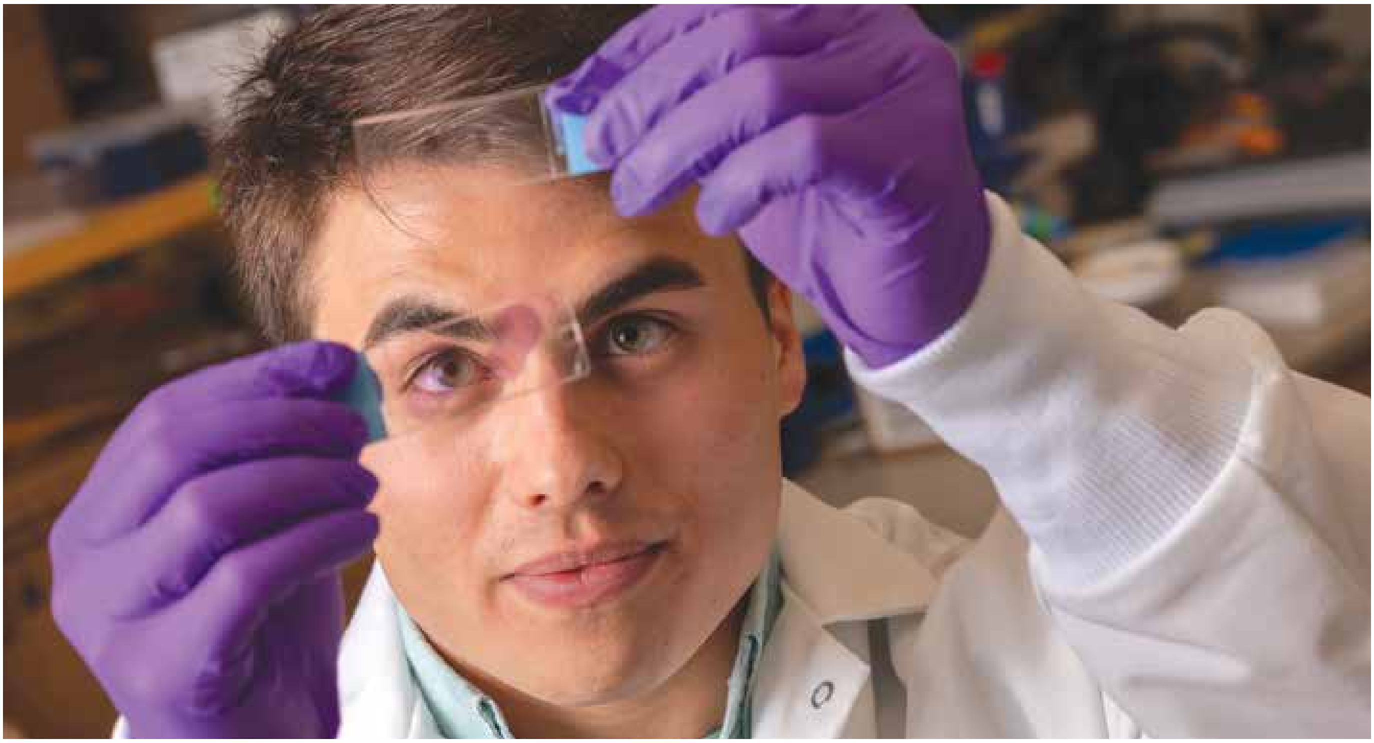
Jewelers consider cut, color, clarity, and carats when evaluating a diamond's worth. But in the quantum world, another quality is more valuable: the presence of nitrogen-vacancy (NV) centers. These light-emitting defects in the jewels' lattice are potent sources of quantum particles that have the potential to be used in sensing applications ranging from biological imaging to electrical and field sensing and more. Until now, it has been challenging to attach NV centers with structures that amplify their optical properties. Ishan Barman, an associate professor of mechanical engineering, has come up with an original solution. He is pairing NV centers with DNA's self-assembling abilities to create high-performance hybrid plasmonic nanodiamonds: infinitesimal diamond-like particles that can control light in unique ways. The innovative approach resulted in the components arranging themselves into a closed nanocavity that surrounded the nanodiamond: an arrangement with a profound impact on the nanodiamond's brightness and emission rates.

HAVING A BALL WITH OPTIMIZATION

Benjamin Grimmer

Benjamin Grimmer designs and analyzes optimization algorithms—a field that is frustratingly abstract to many. So the assistant professor of applied mathematics and statistics is using a 3D printer to turn these complex concepts into colorful, tangible objects that let students explore decision-making across 1D, 2D, and 3D dimensions. Each ball serves as a visual indicator of an operation's strength: its maximum possible efficiency in accomplishing specific tasks or outcomes. The colors denote the problem's level of difficulty: red (challenging) and green (easy). For the golden balls with white bases, the problems' difficulty is an open question. "Real-world optimization problems can have hundreds or thousands of variables, so students really need to use their mathematical brains to extrapolate how to think about them. 3D examples give them one more stepping stone before they have to jump off to work in mathematical generalizations," Grimmer says. ■





Erick Rocher

Improving Medical Care on Many Fronts

IN MIDDLE SCHOOL, ERICK ROCHER WATCHED A FRIEND FIGHT CANCER. THE EXPERIENCE PROVED formative. "There was no doubt I wanted to someday work to improve medical care," he says.

Now a senior biomedical engineering major, Rocher is immersing himself in wide-ranging research, from improving surgical outcomes and innovating training for robotic surgery to harnessing nanotechnology to deliver better cancer treatment.

His efforts have been recognized—and rewarded—with funding from key organizations. In June, he was among four Hopkins students (selected from a national pool of more than 5,000) to earn a Goldwater Scholarship, which honors students committed to pursuing research careers. In August, he joined 68 undergraduates from across the country receiving a scholarship from the Astronaut Scholarship Foundation.

"These scholarships enable me to pursue my research interests at JHU," says Rocher, who also received a JHU Provost's Undergraduate Research Award.

As a first-year student, Rocher joined a student team focused on reducing the surgical time for cataract surgery and improving patient outcomes. "We did a deep investigation into the consequences of temperature on cataract surgery in parallel with prototyping a device to control it," he says.

The team filed a patent on the device and founded ThermOptik LLC, with Rocher as chief research officer. "Recently, I stepped up to the CEO role while continuing to push our research forward," he says.

He concurrently leads a student design team that developed SimMetric, a software package aimed at enhancing coaching provided by robotic surgery simulators through the processing of surgical training data.

"With people like Erick, only the highest mountain will do. That is why he chose to lead in the creation of a powerful tool to help train future surgeons," says Hopkins surgeon Hien Nguyen, associate medical director of the Center for Bioengineering Innovation and Design (CBID) and clinical mentor for SimMetric.

Additionally, Rocher conducts cancer immunotherapy research at the School of Medicine in the labs of Jordan Green and Joel Sunshine. His team is using polymers to form nanoparticles designed to trigger a targeted immune response against tumors.

"At JHU, my passion for biomedical engineering has only deepened the more I've learned," says Rocher, who volunteers as an EMT with Hopkins Emergency Response Organization (HERO) and intends to pursue a MD/PhD. "Hopkins has an incredible ecosystem that is ideal for the kind of multidisciplinary collaboration needed to operate on the cutting edge."

— JULIE WEINGARDEN DUBIN

THIS PAGE: MICHAEL CIESIELSKI; OPPOSITE PAGE: BOTH PHOTOS COURTESY OF KRISTEN CORLAY SANMIGUEL

Kristen Corlay Sanmiguel

"I had a strong interest in how sustainability can coexist with engineering and urban design."

— KRISTEN CORLAY SANMIGUEL

From left to right: Adrita Anika (Texas A&M), Kristen Corlay Sanmiguel (JHU), Sai Sreeshma (Oklahoma State University), and Sukriti Sood (University of Pennsylvania).

Creating Sustainable, Civic-Minded Design

KRISTEN CORLAY SANMIGUEL ARRIVED AS A FIRST-YEAR STUDENT AT HOPKINS INTENT ON improving life in communities like her home city of Monterrey, Mexico. Now a senior majoring in civil and systems engineering, she's made big strides toward that goal—on a variety of fronts.

Last June, Corlay Sanmiguel led a Whiting School undergraduate team to a top-five spot in the finals of the 2023 American Society of Civil Engineers Sustainable Solutions Competition, held at the University of Wisconsin-Platteville. The task? To create a sustainable city block, considering both the environment and the community. The team had to incorporate stormwater management systems, green infrastructure, and multimodal transportation.

"I had a strong interest in how sustainability can coexist with engineering and urban design," says Corlay Sanmiguel. Her team's winning entry included plans for a two-story community center with a sloped green roof and a glass curtain wall with ceramic rods to deflect heat and glare. "It was made out of mass timber, a low-carbon material," she notes.

A year earlier, Corlay Sanmiguel's research on resilience and earthquakes in Mexico City helped her win the Walt Disney data analytics competition and a trip to Disney's Data & Analytics Conference.

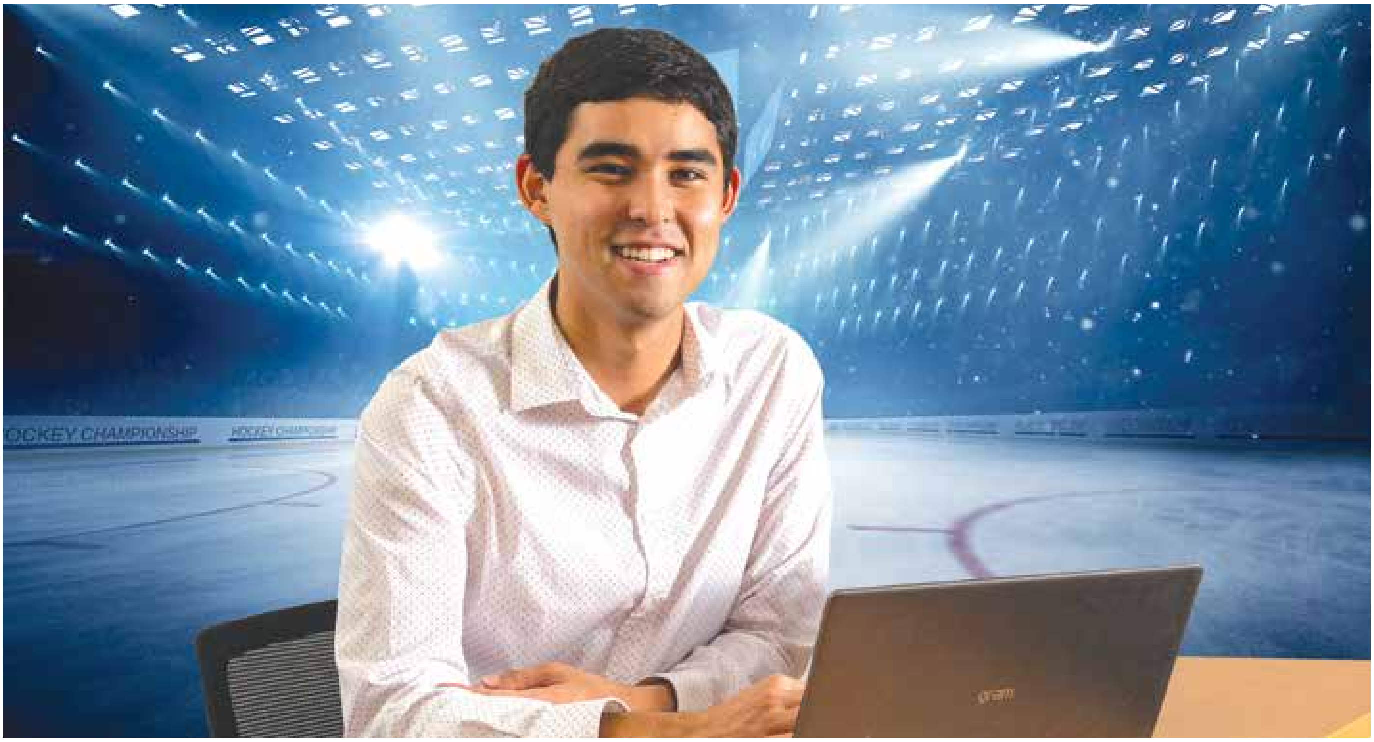
"My dad grew up in Mexico City and I learned about the 1985 Mexico City earthquake from him and my extended family," she says. "The competition was a way for me to put together something so people could see this important story." Her data analysis was informed by an earlier paper in which she examined how earthquakes affect some areas more than others based on land type, and how economic stability is related to increased risk of earthquake damage.

"I made my own code in Python to measure the seismic response spectrum, I ran geospatial data analysis, and I read building codes and policies from the last century up until 2017," she says.

At Hopkins, Corlay Sanmiguel has also continued fine-tuning a web app for civic engagement in Mexico that she launched in 2020 with co-founder Valeria Colunga. "With Cabilde, we are building a database that will make it easier for constituents to find their representatives, bills, and congress voting results," she explains.

Corlay Sanmiguel plans to pursue a master's in urban planning and continue working on Cabilde and data transparency in Mexico. "My goal is to have my own engineering design firm and specialize in Latin American projects relating to sustainability and accessibility in cities," she says.

— JWD



Tad Berkery

Probing the Importance of Faceoffs

ICE HOCKEY ANALYTICS TAKES FACEOFFS INTO CONSIDERATION, BUT CURRENT APPROACHES DON'T go much further than the idea that winning more faceoffs than losing is good for a team.

"How much do faceoffs help teams to win or lose games?" asks Tad Berkery, a senior computer science major. "Existing analytics haven't really mapped faceoffs to scoring outcomes or quantified the value of winning a faceoff."

That's where his project comes in. Collaborating with a team of students from Hopkins Engineering's sports analytics research group, Berkery has harnessed the power of AI and machine learning to determine the true value of the faceoff.

The data set Berkery and the research group used considers more than 5.2 million plays from three hockey analytics sources: Evolving Hockey, Money Puck, and analyst Corey Sznajder.

Berkery and his collaborators—engineering student Max Stevens and recent graduate Justin Nam '23, and Syracuse University graduate Chase Seibold, under the guidance of Whiting School professors Anton Dahbura and Donniell Fishkind—calculated that one faceoff is worth about .015 goals. While that may sound minuscule, with an average of 60 faceoffs per game, the statistic becomes significant.

If a team wins six additional faceoffs per game, it could add 15 goals over the course of an 82-game season, Berkery says. Teams could use the findings for roster construction, he says.

"The project is showcasing how faceoffs are an underpriced market inefficiency that can be exploited: faceoff performance can win games, and you can get people who are good at faceoffs for near league minimum salaries," he says. "It's an answer to the question of not only who's a good player, but also who's a good player that I can get on a below-market deal."

The NHL has taken notice: He presented to one team this summer.

Berkery has always had an interest in sports analytics. In high school, he worked with the University of Maryland softball team and sat in on graduate data science classes at George Mason University. He also created elaborate projections in fantasy football leagues—a skill that won him several championships.

Through the engineering analytics group, Berkery worked on a project with the Baltimore Ravens that analyzed how kickoffs can help win games, and another with the Baltimore Orioles on predicting hitters' performances.

"Sports can be a game of bounces and a game of inches," Berkery says. "There's something really special about combining analytics with athletic talent and luck—to elevate the game and potentially turn a would-be loss into a well-deserved win."

— MARC SHAPIRO

"By using self-supervised learning, models can acquire a similar foundation of knowledge and avoid making silly mistakes."

— YUTONG BAI

Yutong Bai

Bai Named Apple Scholar

YUTONG BAI, A FOURTH-YEAR COMPUTER SCIENCE PHD STUDENT, HAS BEEN NAMED A 2023 APPLE Scholar in AI/ML (artificial intelligence and machine learning). She is one of just 22 graduate students at universities around the world to be recognized by the fellowship program this year.

Bai, who earned a bachelor's degree from Northwestern Polytechnical University in Xi'an, China, works with the Computational Cognition, Vision, and Learning group under the direction of Bloomberg Distinguished Professor of Cognitive Science and Computer Science Alan Yuille. Prior to joining Johns Hopkins, she interned at Google Brain and Meta AI.

Her doctoral research is focused on artificial computer vision systems. Computer vision allows robotic systems to see, process, and respond to their environment; for example, underwater robots recognizing objects on the ocean floor, or smart cars detecting traffic lanes and other vehicles.

In recent work, Bai has developed computer vision models based on self-supervised learning—a powerful method of pretraining AI models that is particularly useful for tasks that do not require labels, such as image recognition.

In traditional supervised learning, an image is paired with a label, such as "dog," and the model is trained to recognize this association. However, Bai's work focuses on training the model before using labeled data. During this pretraining phase, the model performs tasks that do not require human-labeled data. For example, the model may identify whether an image has been rotated or breaks an image down into jigsaw-style pieces. By successfully completing these tasks, the model gathers fundamental knowledge that it can apply to other tasks.

"This is similar to how young children learn about the world around them. They may not know what an apple is, but they learn that objects can be placed near the mouth. When they are taught that an apple is an edible object, they quickly understand the concept because they have already built up a foundation of knowledge," says Bai. "By using self-supervised learning, models can acquire a similar foundation of knowledge and avoid making silly mistakes."

Additionally, Bai's research spans a variety of topics related to advancing what is known as explainable AI, a field that aims to gives designers and users a better understanding of why and how an AI system made its decisions.

Each Apple Scholar in AI/ML will receive support for their research and academic travel for two years, internship opportunities, and a two-year mentorship with an Apple researcher. Bai is the second Johns Hopkins graduate student to receive the recognition.

— CATHERINE GRAHAM

Bridging the Digital Divide in Sub-Saharan Africa

ACCESS TO DEPENDABLE INTERNET AND TECHNOLOGY CAN BE A COMMUNITY'S GATEWAY to economic, political, and informational resources. Emeka Ebo MS '04 saw as much when he helped lay out the first broadband lines that brought internet access to rural communities in Virginia, Maryland, and Pennsylvania while working at Verizon and studying electrical engineering at Johns Hopkins.

The experience made Ebo think about how this same technology could transform communities in his country of birth, Nigeria. He imagined that a company knowledgeable in the local culture and economy could localize a solution to bring similar infrastructure to sub-Saharan Africa.

After a few years of research and transatlantic visits, in 2015 Ebo founded the internet service provider Ekovolt Telco Limited. His company works to deliver affordable internet and data security solutions to underserved areas across three cities in Nigeria, including high-need institutions, like schools and hospitals, that might not be seen as profitable to other providers.

"We speak with some public schools where [purchasing broadband] is not even a conversation because they have other priorities to solve, like having furnished classrooms and the right teachers. It's just not in the forecast for them," he explains.

Ekovolt meets these institutions where they are by working with them in partnership with non-governmental organizations, which provide funding, to ensure the technology's impact is beneficial and sustainable. With a school, for example, Ekovolt leaders might first speak with the principal to determine what technological and knowledge resources they currently have available and how Ekovolt could take them to the next step.

"In some cases, they might not have any resources. So we start with that," says Ebo. "What would it take for you to get trained and build the capacity to receive this equipment and know what to do with it? It's always a journey."

From there, Ekovolt technologists create a personalized work plan for themselves and the school, and routinely re-evaluate the situation to ensure that the technology continues meeting the school's needs.

With larger institutions, such as hospitals, those needs can grow at a breakneck pace and require annual upgrades, particularly with security services. While Ekovolt's current tactics can provide these upgrades, Ebo says that they are looking ahead to a pan-African solution that transcends geographic borders in order for local communities to experience the full benefits of IT solutions and cloud services.

"The demand drives the technology, and so it's constantly evolving."

— ELENA CONWAY

Emeka Ebo

OPPOSITE PAGE: PHOTO COURTESY OF PAIGE SENAL, PHOTOGRAPHED BY DAVID LIN.

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Paige Senal

“I remember seeing ads on the subway celebrating the NBA’s 75th anniversary season. There were promotions all over the city to download the app, and I knew I helped build something that brought people joy.”

— PAIGE SENAL

Building NBA Analytics

WHEN PAIGE SENAL ’17 WAS A FIRST-YEAR STUDENT AT THE Whiting School, she imagined a future working to save the planet. She never dreamed that six years later, she would be building analytics for the National Basketball Association (NBA).

Senal is a software engineer on the Product Analytics Engineering team, where she designs, implements, and tests product analytics across the NBA’s digital properties, including the organization’s website and mobile and TV apps.

Her team’s work includes measuring what content viewers are watching and for how long on video, as well as analyzing what’s driving fans to subscribe to League Pass, the league’s premier subscription-based streaming service, which is available via the NBA app. “It provides fans the ability to watch live games and highlights and check scores, statistics, and standings all in one place, and it offers additional videos and series such as ‘Pass the Rock,’ which follows the league’s new generation of players,” she says.

Senal notes that 99% of fans around the world will never step foot in an arena, “which only underscores the importance of using the NBA app to deliver localized and in-language content that engages them year-round.”

She is particularly proud of her work on the NBA’s app redesign, which launched in 2022. “I remember seeing ads on the [New York City] subway celebrating the NBA’s 75th anniversary season,” says Senal. “There were promotions all over the city to download the app, and I knew I helped build something that brought people joy.”

At Hopkins, Senal initially planned to major in environmental engineering. But then a required computer programming course resulted in a Eureka moment: “I was doing coding and it was awesome,” she says. “I switched my major to computer science.”

In her junior year, attending the Grace Hopper Celebration in Computing—the world’s largest gathering of women technologists—proved to be yet another defining experience. “It was my Disney World for meeting people in the industry,” she says. “Sheryl Sandberg [Meta chief operating officer at the time] was a guest speaker. She said if you take anything away from this conference, it’s to form communities of women in engineering so you can lean on other women.”

“That changed everything for me. I needed to lean on others at Hopkins within my major to get myself through. I became co-founder and president of Women in Computer Science at JHU,” she says, adding, “My time at Hopkins gave me the tools to succeed and a sense of self that can’t be taken away.”

— JULIE WEINGARDEN DUBIN

A panoramic view of the High Line promenade in Manhattan.

Craig Schwitter

Designing Iconic Environments

CRAIG SCHWITTER '89 IS A PASSIONATE ADVOCATE FOR INTEGRATING ENGINEERING, ARCHITECTURAL design, and rapid advances in technology to improve people's lives. And that means considering every aspect of a project's possible impacts on a community—from health and the local economy to climate change.

At Buro Happold, a global engineering and advisory practice with offices throughout the United States, Schwitter has led collaborations with cities, corporations, colleges, and some of the world's leading architects to build not just structures, but iconic environments. With a background in structural engineering, Schwitter joined the firm in 1992 and currently serves as both senior partner and global board chair.

Schwitter and Buro Happold are committed to Net Zero, the movement to completely negate the amount of greenhouse gases produced by human activity. "Sustainability is increasingly important to our clients. The tools are there, and I am incredibly optimistic," says Schwitter, who majored in civil engineering at the Whiting School, and then went on to earn a master's in civil engineering at MIT.

His many projects include New York City's High Line, the celebrated transformation of a long-abandoned stretch of an elevated Manhattan rail line into a public park overlooking the Hudson River. There is also the "breathable" bank building in Pittsburgh, a sun-drenched 33-floor edifice with a sophisticated double-skin ventilation system. Buro Happold also led work on Atlanta's Mercedes Benz Stadium with its impossibly elegant (and technically challenging) retractable roof, made of eight translucent "petals" that open like the eye of a camera.

Perhaps most technically and aesthetically dazzling of all, there is the Jewel at Singapore's Changi Airport, a 1.4-million-square-foot glass-enclosed entertainment and shopping complex. It features a seven-story rain-fed waterfall and terraced forest topped by a stunning "grid-shell" roof made possible only by recent advances in computer-generated parts and design.

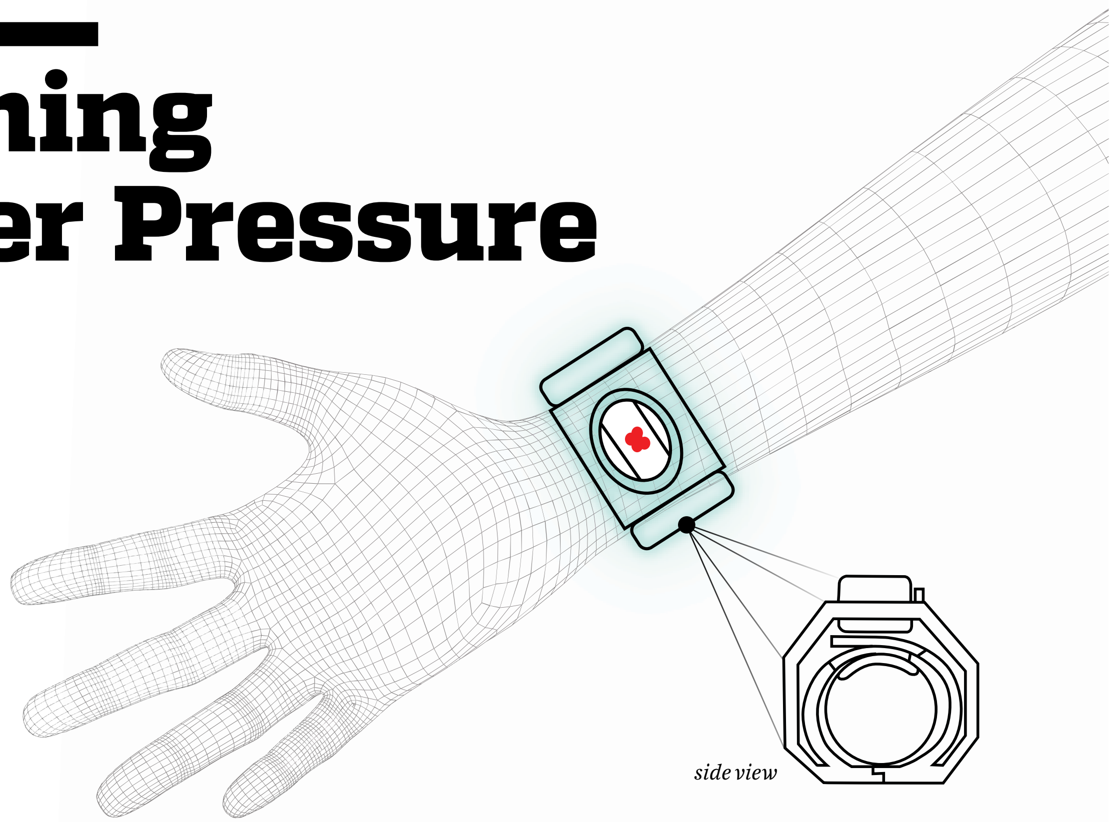
"Collaboration is the key. You need everyone's expertise," says Schwitter, who has been an industry advisor to the U.S. State Department and has taught at Columbia University's graduate school of architecture, where he helped develop a curriculum for teaching technology to architects.

But he also believes his most important collaborators are the people destined to use the spaces. "Once in a while, when I have a few minutes in New York, I go up on the High Line and just sit and watch people walk and talk and enjoy themselves. I can't think of anything more satisfying."

— JOAN CRAMER

THIS PAGE: PHOTO OF CRAIG SCHWITTER COURTESY OF BURO HAPPOLD.

Pitching Under Pressure



WHILE WORKING FOR COMPANIES IN THE FIELD OF STERILITY ASSURANCE, NICK DESANTIS '12, MS '18, didn't find many opportunities to contribute to the design concept development of new products. But that changed when he began working for Cordis, a medical device company specializing in cardiovascular devices. They made it clear they were welcoming new ideas, so he sent them a final project presentation he'd completed for a class in the Applied Biomedical Engineering program at Johns Hopkins Engineering for Professionals.

His school assignment? To design and market a new product in the cardiovascular space through a *Shark Tank*–style pitch video.

Inspired by his background in sterilization procedures, DeSantis pitched a hemostasis pressure device that utilizes reusable parts. At the conclusion of a transradial cardiac catheterization procedure, where a doctor accesses the heart through the wrist's radial artery, these devices are commonly used to prevent bleeding at the access point and help the tissue heal by applying pressure to the area.

Current versions of the device can only be used once; but DeSantis's design breaks the device down into two main components: a disposable inner cuff that comes in contact with the patient's skin and a reusable outer part that applies the pressure and can be sterilized with equipment already commonly found in hospitals.

For hospitals, the design's reusability would cut down the cost of supplies and help curb medical waste, particularly since the reduced risk of complications from transradial procedures, as opposed to transfemoral, makes them an increasingly preferred method for treating and diagnosing heart conditions. For DeSantis, presenting the design to his employers marked a turning point in his career.

"It was awesome to have my ideas taken seriously and pursued by the R&D and legal teams, even though I was not in an R&D role at the time," he says of the experience. "The *Shark Tank* style at first seemed excessive, but it was more fun and definitely got their attention. I also think being in a Johns Hopkins biomedical engineering program gave me more credibility and helped get my foot in the door."

Since pitching it, DeSantis has secured a patent on his device through Cordis, and he was able to move into a device design and development role with a new employer, thanks in part to the experience. It's also encouraged him to try to patent more of his designs.

"It is exciting that the EP program has brought these opportunities to my career," he says.

— EC

Nick DeSantis

A Forum for Fruit

Scott Smith

"That's why I started my own fruit-growing forum. It's pretty active, with several posts an hour. We even have some young people who are big contributors; it's all different ages, all different stripes."

— SCOTT SMITH

SCOTT SMITH IS MORE THAN FAMILIAR WITH DEBUGGING—WHETHER IT'S IN LINES OF COMPUTER code or amid the rows of his orchard.

The director of graduate studies and a professor in the Department of Computer Science, Smith has been growing fruit in his north Baltimore backyard for more than 20 years, but his love of homegrown produce reaches back to his early childhood when he first plucked cherries from his family's tree when he was three.

Smith was inspired to try growing his own fruit in 2002 as a respite from his research on programming languages. "One cold, dismal March day, I got this fruit tree catalog in the mail," he says. "There were all these beautiful pictures of fruit—such a bounty!—and I said, 'Okay, I'll order a couple of things.'"

A "couple" has turned into two full orchards—replete with various types of fruit, from apples to kiwis to persimmons. He now has plans for a vegetable garden to round out his acre of suburban land.

Smith learned most of what he knows about growing online. But he also benefited from the guidance and mentorship provided by local growers—and, like a true scientist, he wanted to give back to the fruit "research" community, too.

"That's why I started my own fruit-growing forum," says Smith. "It's pretty active, with several posts an hour. We even have some young people who are big contributors; it's all different ages, all different stripes."

The online forum boasts 5,000 active users and 700,000 posts, and even has a trading post where enthusiasts can trade growing tips and grafting sticks.

When he's not moderating the forum or directing the Programming Languages Laboratory, Smith can be found outside in his orchard, planting, pruning, harvesting, and, of course, "debugging"—albeit with a low-impact, nontoxic spray regimen.

— JAIMIE PATTERSON

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Gearing up for Grad School

Being accepted to the Whiting School of Engineering's PhD program in chemical and biomolecular engineering was Chun-Chiao Yang's first challenge. The second? Moving from San Francisco to Baltimore. So he hopped on his bicycle: a 2015 Giant Defy 3.

Calling his trip "The Grand Commute," Yang, who came to Johns Hopkins after three years as a research scientist at a biotech company, spent 69 days traversing the 4,040 miles from California through Nevada, Utah, Colorado, Kansas, Missouri, Kentucky, Virginia, Washington, D.C., and finally Maryland. On the way, he documented the trip on Instagram.

"I have driven to Lake Tahoe several times, but it is not until I rode it that I realized what 8,500-feet elevation actually means," one post read. Traveling further east he wrote, "Colorado is your most adventurous and outdoorsy friend who is always wild. Kansas is the reserved and taciturn one that you can be with all night long during a stormy night." His favorite part: the Ozark National Scenic Riverways in Missouri, where he took time out for a canoe trip.

Yang plans to continue cycling in the Baltimore area.

—JONATHAN DEUTSCHMAN