THE JOHNS HOPKINS WHITING SCHOOL OF ENGINEERING MAGAZINE

JHU ENGINEERING

WINTER 2022

Tantalizing Advances in Tissue Regeneration

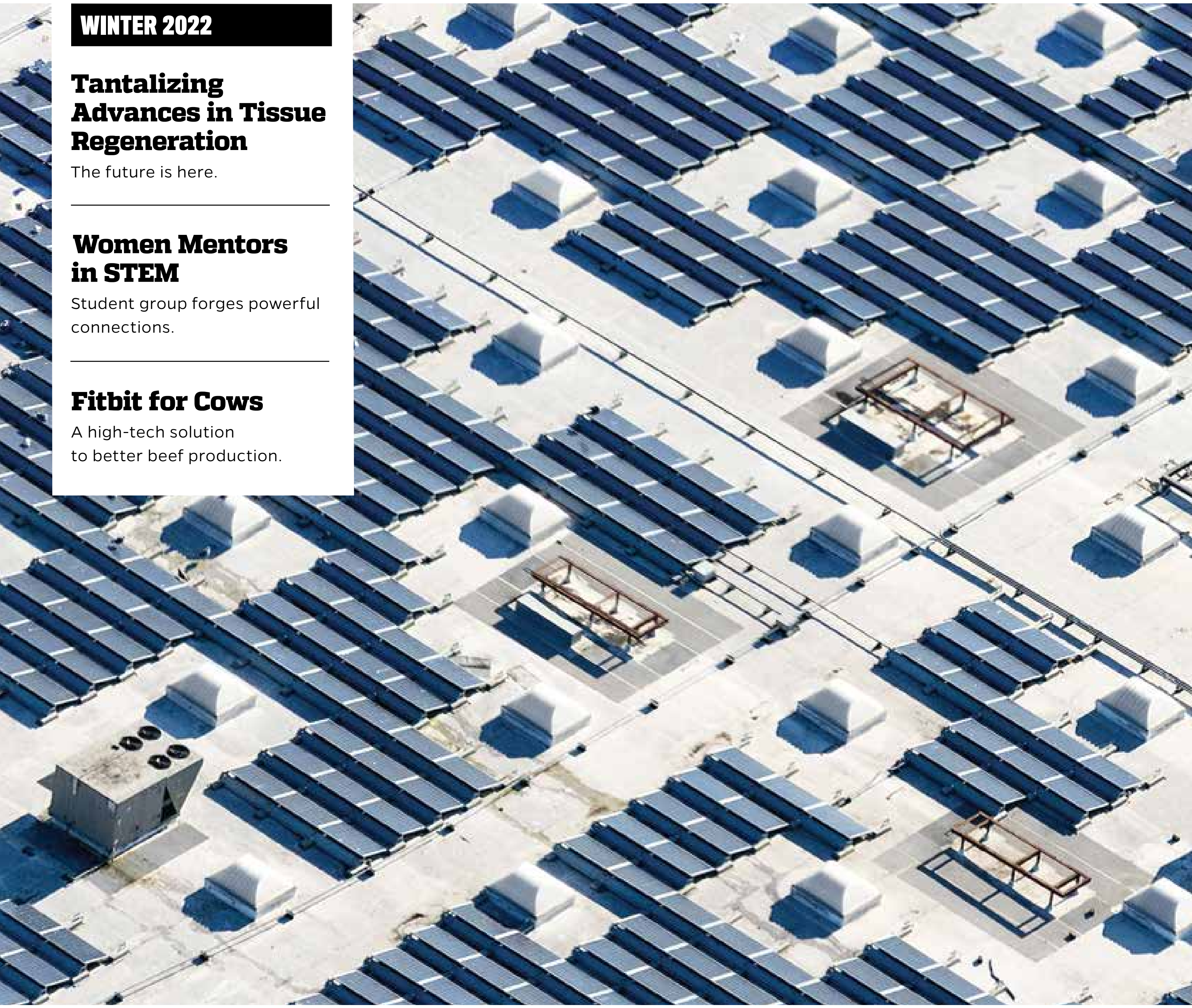
The future is here.

Women Mentors in STEM

Student group forges powerful connections.

Fitbit for Cows

A high-tech solution
to better beef production.



Reimagining Renewable Energy

There's no time to waste in creating scalable, renewable energy technologies.

FROM THE DEAN

Dear WSE community,

TODAY AS NEVER BEFORE, ENGINEERS AND ENGINEERING IMPACT JUST ABOUT EVERY ASPECT OF OUR lives—from our understanding of how infectious diseases spread and the reliability of the power grid to commerce, social interactions, and even political discourse. It is difficult to identify a human activity today that is not in some way shaped or enabled through technology.

As the pace of this world-altering technological innovation accelerates and as our reliance on technology increases, a troubling trend has emerged: a growing gap between society's overall dependence on technology and our understanding of it. This disconnect threatens our personal safety, national security, cohesion, and global competitiveness. It also makes us susceptible to the kinds of misinformation and misunderstanding that can cause people to be suspicious of the very systems underpinning society.

For our profession's sake and, more importantly, to improve lives on a global scale, we must close this knowledge gap, and this is a place where I believe Johns Hopkins Engineering can make a real and lasting difference.

We can employ our resources and expertise to provide a new kind of engineering education: one that offers opportunities to both traditional and nontraditional students and is challenging, relevant, inclusive, and equitable. In doing so, we can equip people with the knowledge and problem-solving skills needed to demystify technology and understand its risks and benefits, helping forge new pathways that spur curiosity, discovery, and innovation.

Not only do I look forward to sharing our successes with you as a school, but also to partnering with you as we make the vision of an informed and empowered citizenry a reality.

Wishing you good health and well-being,

ED SCHLESINGER
Benjamin T. Rome Dean

CONTRIBUTORS

GORDON STUDER

TISSUE ENGINEERING: THE FUTURE IS HERE (P. 12)
Studer, an illustrator based in Emeryville, California, was one of the first illustrators in the country to work digitally. His corporate and editorial clients include AT&T, TIME, Adobe, and *The New York Times*. He has also taught at the California College of the Arts.

KAREN BLUM

TISSUE ENGINEERING: THE FUTURE IS HERE (P.12)
Blum is a Baltimore-based freelance health and science writer who covers health, medicine, and science for a variety of outlets, including several Johns Hopkins publications. Her articles have appeared in *The Baltimore Sun, Anesthesiology News, Ophthalmology Management,* and MedPageToday.com, among others.

ABOUT THIS MAGAZINE

Editor
Abby Lattes

Consulting Editor
Sue De Pasquale

Art Direction and Design
Cut Once, Inc. (cutoncedesign.com)

Associate Dean for External Relations
Megan Howie

Director of Communications
Abby Lattes

Director of Constituent Engagement
Kim Sheehan Dolan KSAS '13, MS '18

Contributing Writers:
Sarah Achenbach, Karen Blum, Wick Eisenberg, Lisa DeNike Ercolano, Catherine Graham, Adam Hadhazy, Will Howard, Danny Jacobs, Jill Rosen, Christina Hernandez Sherwood, Gina Wadas, and Vanessa Wasta

Contributing Photographers and Illustrators:
Will Kirk (A&S '99)/Homewood Photo, Matt Chase, Lydia Gregg, Ian Suk

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We encourage your comments and feedback. Please contact us at:

Abby Lattes: alattes@jhu.edu
Editor
Whiting School of Engineering

To update your mailing address or order additional copies, email engineering@jhu.edu or call 410-516-8723.

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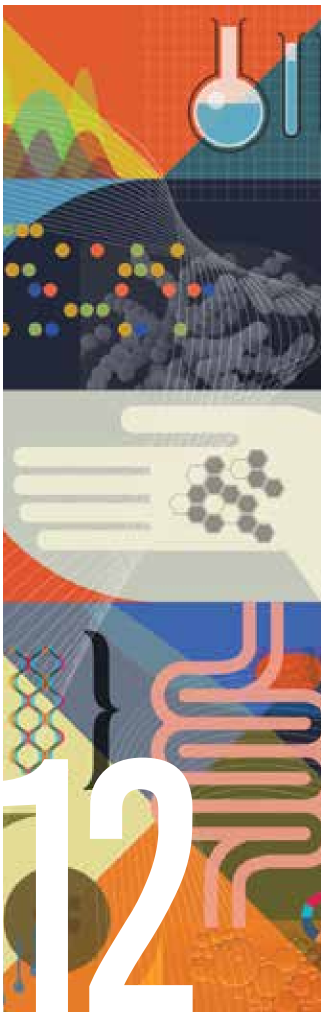
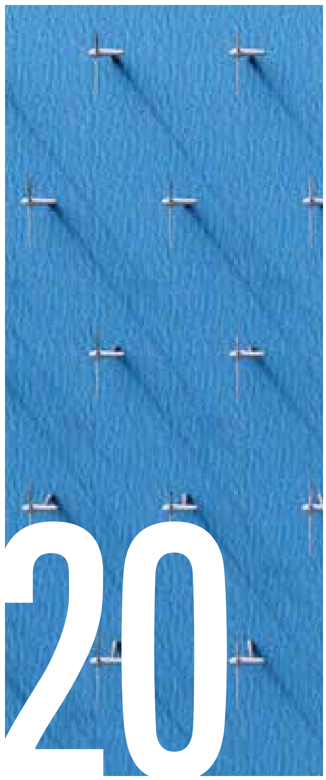
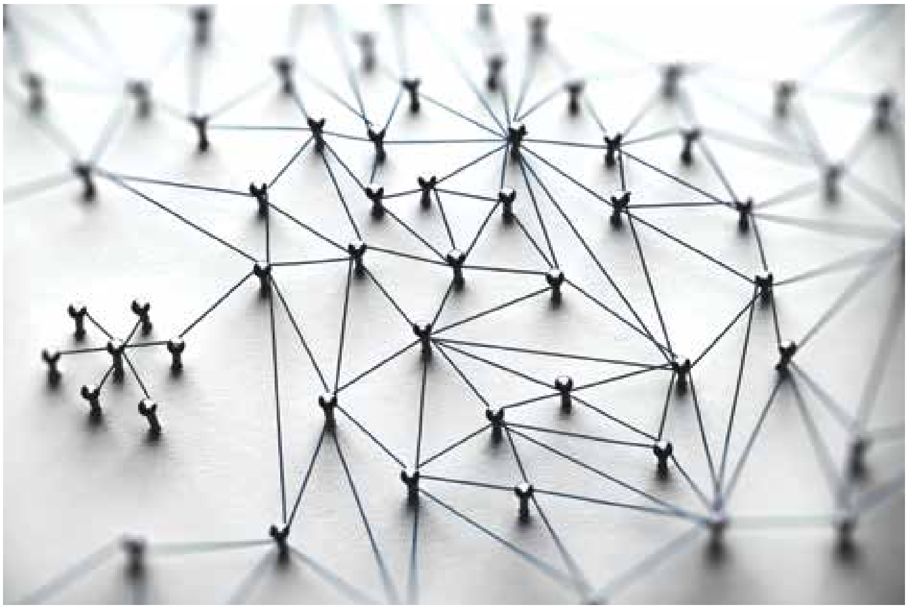
WINTER 2022





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



COVID-19: Overcoming Data Deficiencies

SINCE THE START OF THE COVID-19 PANDEMIC, JOHNS HOPKINS UNIVERSITY experts at the Coronavirus Resource Center have had a behind-the-scenes view on how state, federal, and global agencies collected and reported COVID-19 data. Their analyses revealed a troubling truth: In the absence of standards and uniform methods, the states used an uneven patchwork of policies and disjointed reporting.

Enter the CRC's Pandemic Data Initiative — a resource launched last spring to spotlight systemic deficiencies in the collecting and reporting of pandemic data, examine how those challenges hinder COVID-19 responses, and explore possible solutions to improve public data.

Last summer, researchers with the initiative first warned of a troubling trend of U.S. states eliminating daily reporting of COVID-19 data. The reduction in daily reporting on cases, hospitalizations, deaths, and other vital data took place at a time when more public data were needed—as the highly transmissible Delta variant drove a new surge in the pandemic, noted Lauren Gardner, chief architect of the CRC's global dashboard and director of the Center for Systems Science and Engineering in the Whiting School.

States had demonstrated they had the infrastructure and capacity to report data daily. "However, instead of investing in sustaining the infrastructure already established, states are, more often, scaling back," noted Gardner in August, commenting on an analysis she completed with Beth Blauer, the university's associate vice provost for public sector innovation.

The need for states to provide reliable, standardized data became more critical than ever this fall with the emergence of the highly-contagious Omicron variant.

"Unfortunately, many states are limiting or stopping public reporting of vital data, a move that will limit the nation's ability to anticipate disease spread," says Blauer.

— JILL ROSEN

Access the Pandemic Data Initiative website through coronavirus.jhu.edu to find regularly updated analyses spotlighting data challenges and irregularities.

NEW NAME, EXPANDED MISSION

When MARCC (the Maryland Advanced Research Computing Center) launched in 2015 on the campus of Johns Hopkins Bayview Medical Center, it was hailed as one of the nation's largest academic high-performance computing centers. MARCC's swift fiber-optic cable connections let investigators conduct research on everything from deadly diseases to distant galaxies without leaving their laboratories or offices, and participants shared the costs.

Now MARCC has a new name and an enhanced mission. It has become ARCH (Advanced Research Computing at Hopkins), an expanded facility designed to sustain advanced and data-intensive computing growth, and enable innovative, dynamic, and life-improving computational discoveries.

Like MARCC, ARCH is structured on a model called "condo computing": Users buy their own nodes and have them installed in a central cluster. Researchers then have priority access not only to the resources they purchased but also to those of other researchers in the cluster.

ARCH management has plans to partner closely with the Johns Hopkins Institute for Data Intensive Engineering and Science to facilitate a seamless process of data sharing.

"We see ARCH becoming a critical resource to initiatives here at Hopkins that are developing and applying AI and machine learning to improve the lives of people on our fragile planet," says Paulette Clancy, head of the Department of Chemical and Biomolecular Engineering and chair of the faculty oversight group for ARCH.

— LISA DENIKE ERCOLANO

OPPOSITE PAGE: WILL KIRK/HOMEWOODPHOTO.JHU.EDU.

ROBBINS PRIZES AWARDED

Mark O. Robbins

Three Whiting School of Engineering affiliates are inaugural winners of prizes established to honor the legacy of renowned condensed matter and statistical physicist Mark O. Robbins, who died in 2020.

The winners of the Mark O. Robbins Prize in High-Performance Computing are Karthik Menon, a doctoral candidate and member of Rajat Mittal's lab in the Department of Mechanical Engineering, and Andrew Ruttinger, a doctoral candidate and a member of Paulette Clancy's lab in the Department of Chemical and Biomolecular Engineering.

Menon's research focuses on the development of computational and data-driven techniques to study the interaction of fluids with flexible and moving surfaces within liquid flows. Ruttinger focuses on using computational modeling to develop insights into quantum dot photovoltaics, lithium extraction from low-concentration sources, and the development of thermal energy storage.

Postdoctoral fellow Sai Pooja Mahajan is the winner of the Robbins Future Faculty Award. She focuses on developing and applying computational techniques aimed at solving complex problems in computational lithography and computational protein structure, function, and design. She is a member of Jeffrey Gray's lab in the Department of Chemical and Biomolecular Engineering.

All three honorees received cash prizes and plaques, and were invited to present their work at a virtual High Performance Computing Symposium held last August.

— LDE

Willa Grinsfelder '21

Top Showing in Student Wind Competition

A TEAM OF JOHNS HOPKINS UNIVERSITY STUDENTS TOOK HOME SECOND PLACE AT THIS YEAR'S U.S. Department of Energy Collegiate Wind Competition, held virtually June 2–11.

This was Johns Hopkins' first appearance at the annual national competition, which challenged 13 undergraduate teams from around the country to offer solutions to a complex wind energy problem. Over the course of the academic year, the teams designed, built, and tested model wind turbines; developed wind farm project plans; collaborated with industry experts; and raised awareness of wind energy in their local communities. Johns Hopkins came in just behind the team from Pennsylvania State University.

"Our team's goal was to build a strong foundation in wind energy topics, and I think we were all prepared to run with the middle of the pack this year. We were surprised and excited to have finished so well in our first competition. Every single member of our team worked so hard to bring ideas and designs to the competition, and to see that recognized was a great way to end the year," says Willa Grinsfelder '21, leader of the Johns Hopkins Student Wind Energy Team.

The team's strong finish in the competition exemplifies Johns Hopkins students' growing interest in wind and renewable energy, says Grinsfelder. And that's a good thing, because Johns Hopkins has already been selected to participate in the 2022 Collegiate Wind Competition in San Antonio, Texas.

"A great thing about the Johns Hopkins Student Wind Energy Team is that it gives senior members an opportunity to mentor underclassmen and pass on what they've learned," she says. "We're really excited about building this network and to see our members have continued success at future competitions."

— CATHERINE GRAHAM

Empowering Girls to Navigate Adolescence

The JHU team worked with teenage girls from the White Mountain Apache Tribe in Whiteriver, Arizona.

NATIVE AMERICAN GIRLS GROWING UP IN TRIBAL COMMUNITIES BENEFIT from a close connection to their tribes' rich histories, customs, and traditions.

But in adolescence, these girls also experience rates of substance abuse, unintended pregnancy, and sexually transmitted diseases that can be two to four times higher than those of peers across the U.S. They're also at greater risk for physical, sexual, and emotional abuse.

To help them navigate this oft-perilous time in their lives by engaging the strengths of their cultures, a Johns Hopkins engineer is partnering with other Johns Hopkins University researchers to put helpful resources directly into the girls' hands through a smartphone app called Safe Passage.

"With the app, information on everything from the biology of puberty to emotional and relationship issues, as well as how to quickly get in touch with people who can help, is as close as their smartphones," says Tak Igusa, professor of civil and systems engineering with a joint appointment in the Bloomberg School of Public Health.

The app development team is led by Allison Barlow, director of the Johns Hopkins Center for American Indian Health, and co-project lead Teresa Brockie, assistant professor in the School of Nursing and a member of Montana's White Clay Nation, as well as partners — including teenage girls — from the White Mountain Apache Tribe in Arizona and from the Sioux and Assiniboine nations at the Fort Peck Reservation in Montana.

It quickly became clear that simply adapting an already available app wouldn't work for this project.

"Tech companies make a lot of marvelous apps, but their business model is, 'We will show you how it's done,' and that wasn't the approach we wanted to take," says Igusa, who is leading the app design. "We wanted to learn from the community."

To this end, the Johns Hopkins team has spent several years working closely with tribal leaders, adolescent girls, and their parents, as well as with teachers and health care workers, carefully teasing out the most important issues to address.

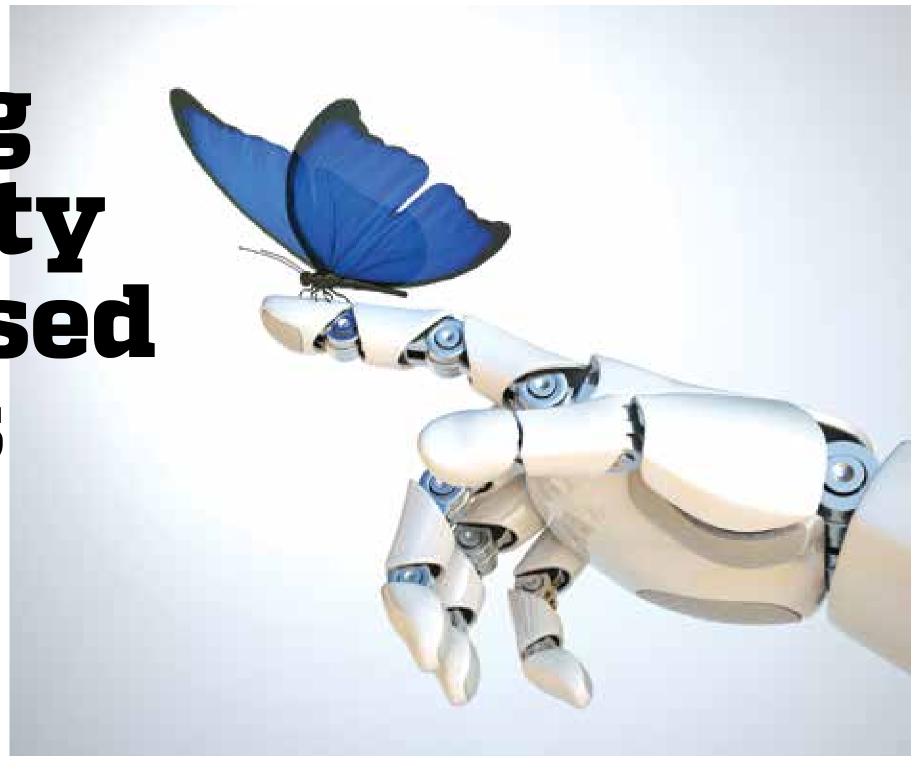
In the summer of 2019, a group of girls from the reservations traveled to Baltimore to workshop ideas with the Baltimore team. They spent a week developing quizzes on relationships and reproductive health; writing and recording scripts for content about birth control, pregnancy, and menstruation; creating journaling prompts; and more.

Despite pandemic-caused delays, the team expects the first iteration of the app will launch this year.

— LISA DENIKE ERCOLANO

THIS PAGE: PHOTO COURTESY OF ED CUNICELLI, JOHNS HOPKINS CENTER FOR AMERICAN INDIAN HEALTH.

Ensuring the Safety of AI-Based Systems



USING A $7.5 MILLION, FIVE-YEAR GRANT FROM THE U.S. DEPARTMENT OF DEFENSE, A MULTI-UNIVERSITY team that includes Johns Hopkins engineers is tackling one of today's most complex and important technological challenges: how to ensure the safety of autonomous systems, from self-driving cars and aerial delivery drones to robotic surgical assistants.

"The potential practical ramifications of this project are broad and boil down to making sure that artificial intelligence-based systems are safe," says René Vidal, the Herschel L. Seder Professor of Biomedical Engineering and the inaugural director of the Mathematical Institute for Data Science. He is working with Noah Cowan, professor of mechanical engineering and director of the Locomotion in Mechanical and Biological Systems laboratory, and collaborators at Northeastern University, the University of Michigan, and the University of California, Berkeley on the Multidisciplinary University Research Initiative, or MURI project, called Control and Learning Enabled Verifiable Robust AI, or CLEVR-AI.

"Using this grant," says Vidal, "we are developing theoretical and algorithmic foundations to support a new class of verifiable, safe, AI-enabled dynamical systems that, like living systems, will adapt to novel scenarios, where data are generated — and decisions are made — in real time."

Despite recent advances in artificial intelligence and machine learning, the goal of designing control systems capable of fully using AI/machine learning methods to learn from and interact with the environment the way humans and animals do remains elusive, the researchers say.

"Animals, including humans, move with such grace and agility, and are able to adjust and change their movements and behavior according to what is happening around them," says Cowan. "As engineers, we seek to learn from them while creating robust control systems that are safe and reliable. Our goal here is to bridge the gap between biological sensing and control systems, and safe and reliable autonomous systems."

The field of artificial intelligence has tried to address this gap by building computational systems that attempt to mimic or approximate aspects of the brain. Unfortunately, that approach and the resulting designs do not reliably create safe systems. The team's project seeks to overcome this by combining machine learning, dynamical systems theory, and formal verification methods, leveraging each team member's strengths. For instance, Vidal is an expert in machine learning, computer vision, and biomedical data science, and Cowan's expertise is in understanding sensing, computation, and control in animals. Both are leading authorities in the field of robotics and control theory.

"Our approach," says Cowan, "will integrate traditional mathematical control theory with new and emerging AI to make systems verifiable, robust, safe, and correct."

— LDE

"Our aim is to provide patients with as much information as possible so they can make informed decisions to guide their own personal health."

— JOSHUA DOLOFF

Smoothing the Way to Better Breast Implants

SILICONE BREAST IMPLANTS WITH A SMOOTHER SURFACE DESIGN have less risk of producing inflammation and other immune system reactions than those with more roughly textured coatings, according to new research by Joshua Doloff, assistant professor of biomedical engineering, who collaborated with researchers at Johns Hopkins Medicine, MIT, and Rice University on a series of experiments published last June in *Nature Biomedical Engineering.*

Results of the studies using mice, rabbits, and samples of human breast tissue advance knowledge of how the body responds to such implants, providing new information to physicians and affirming the benefits of certain smoother surfaces, say the researchers.

Breast implants, surgically inserted following mastectomies or to augment breast size, can be filled with either saline or silicone, but both types have a silicone outer shell. Previous studies showed that most of the 400,000 women each year in the U.S. who receive silicone implants will need to have them replaced within 10 years because of pain and shape shifting of the implant caused by immune system cells that contribute to scarring and fibrous tissue.

"Our aim is to provide patients with as much information as possible so they can make informed decisions to guide their own personal health," says Doloff, first author of the research, which began during his postdoctoral training at MIT.

Doloff, whose research overall focuses on the interface between implantable devices and the human body, says scientists have long known that the immune system biologically walls off foreign objects in the body by creating inflammation and scarring that can be disfiguring and painful. For the past decade, scientists have been examining how to design implant surfaces in ways that reduce such effects.

He notes other areas of active research for implantable devices include development of biosensors that can detect rupture, leakage, or inflammation of surrounding tissue. He also plans to study the amount of immune response, inflammation, and fibrous tissue among implants in women following cancer diagnosis and treatment.

"Engineers should know how something works, not just that it works, so we can improve on existing technologies," says Doloff.

— VANESSA WASTA

Targeting the Mechanisms of Metastasis

BY LAUNCHING ABMETA THERAPEUTICS, A STARTUP AIMED AT DEVELOPING ANTI-METASTATIC THERAPIES BASED ON ENGINEERED antibodies, Denis Wirtz has served as a real-life example of the high value that Johns Hopkins places on entrepreneurship.

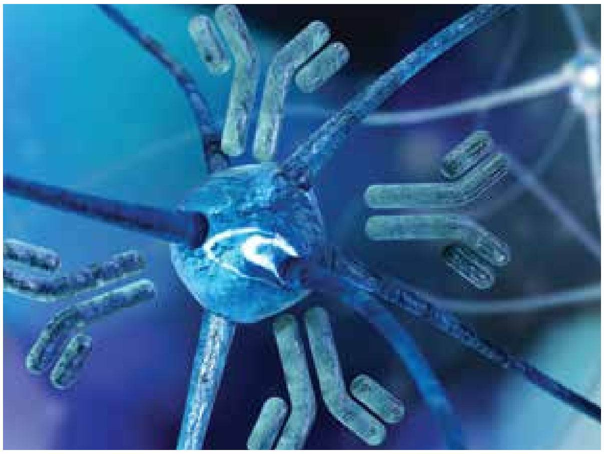
"Now I can honestly say, 'If I can do it, everyone can do it,'" says Wirtz, the Theophilus Halley Smoot Professor in the Department of Chemical and Biomolecular Engineering and vice provost for research at Johns Hopkins University.

Wirtz formed AbMeta in fall 2020 with Jamie Spangler, the William R. Brody Faculty Scholar in the departments of Biomedical Engineering and Chemical and Biomolecular Engineering, and Elizabeth Jaffee, deputy director of the Johns Hopkins Kimmel Cancer Center.

The company initially plans to target pancreatic and triple-negative breast cancer, two of the more aggressive forms of the disease, and aims to test its therapy in patients in the next five years. The startup has already secured nearly $2 million in funding, thanks to a grant from the Bisciotti Foundation Translational Fund, through Johns Hopkins Technology Ventures, and investment from IP Group, a hard science investment firm that discovers and builds early-stage companies.

Wirtz says his experience with the startup confers credibility in his advocacy for entrepreneurship, noting, "Now I can say even to colleagues with seniority that they should, as a way of measuring their impact, develop tech that is used in the real world and not just rely on journal articles to reach peers about their work."

— **DANNY JACOBS**



3 Questions

Interview by Lisa DeNike Ercolano

Most Americans take safe, clean drinking water for granted, not realizing that what's flowing from their faucets likely contains myriad potentially harmful chemicals in mixtures that are increasingly complex and whose health effects on humans are largely unknown.

Enter Johns Hopkins engineers Carsten Prasse and Paul Ferraro, who propose a new approach to assessing water quality. Prasse, assistant professor of environmental health and engineering, says the key to the new method's success is its focus on chemical mixtures circulating in water, rather than on individual contaminants.

1 Describe your new approach.

Our MiAMI (Mixture, Assay, Measure, Innovate) approach leverages advances in bioassays, measurement of complex chemical mixtures, and artificial intelligence to identify previously unknown chemical mixtures in water, enabling the creation of engineering and policy approaches that ensure that water from individual drinking water systems is safe. This will allow for the creation of engineering and policy approaches that are tailored toward individual water systems. Professor Ferraro and I envision this as a sort of "precision health" for water.

2 How are precision/individualized health for humans and MiAMI similar?

In precision health, clinicians use all available information to come up with a customized and holistic treatment plan for a patient, rather than treating the patient as a separate set of diseases. MiAMI would use a similar approach, looking comprehensively at each water system and its individual attributes. MiAMI's goals are to help identify health risks in water and provide a road map for reducing those risks.

3 What risk mitigation methods could result from MiAMI analysis?

Solutions could include everything from removing contaminants from source waters and finding ways to minimize toxic byproducts that are formed during water treatment to laws that prohibit the production or use of contaminants, and even market mechanisms that could make producing and using certain chemicals more expensive.

A BETTER ALERT FOR FETAL DISTRESS 1

Restriction of the flow of blood or oxygen to brains of fetuses during labor and delivery can result in cerebral palsy, cognitive issues, and developmental delays. Of the nearly 4 million babies born each year in the United States, the incidence of this condition, known as hypoxic-ischemic encephalopathy, is one to three per every 1,000 full-term infants.

Electronic fetal monitoring, which since 1970 has been used on more than 85% of laboring patients, has a higher than 99% false positive rate in predicting cerebral palsy.

Ernest Graham, professor of obstetrics and gynecology, and Raymond C. Koehler, professor of anesthesiology and critical care medicine, started a collaboration with Whiting School engineers Emad Boctor, associate research professor in the Laboratory for Computational Sensing and Robotics, and Jeeun Kang, a research scientist with the Laboratory for Computational Science and Robotics and MUSiiC (Medical UltraSound Imaging and Intervention Collaboration), to design an ultrasonic, photoacoustic endovaginal imaging device that monitors the fetal brain during labor and can more accurately predict serious fetal distress.

"Our hypothesis is that continuous monitoring of fetal brain health and labor progress during labor will produce valuable diagnostic perspectives to pediatricians and obstetricians for prompt detection and treatment of fetal HIE and stroke," Kang says.

The system also measures the mother's cervical dilation and effacement, eliminating the need for clinicians to repeatedly perform uncomfortable and invasive checks.

The team started this collaboration a few years ago with seed funding from the Department of Acute and Critical Care Medicine and the Institute for Clinical and Translational Research. The work was enabled by a Discovery award from the Office of the Provost, Boctor's National Science Foundation CAREER grant, and National Institutes of Health R01 MPI (Koehler, Boctor, Graham). Using support from a JHTV translational fund, the team is building a clinical prototype.

— LISA DENIKE ERCOLANO

MORE ACCURACY IN DIAGNOSING EPILEPSY 2

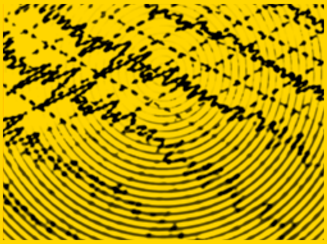
More than 3 million Americans have epilepsy, a neurological disorder characterized by unpredictable seizures. For almost 100 years, doctors have diagnosed epilepsy with a scalp electroencephalography (EEG) head scan, looking for abnormalities in the scanned brain waves between seizures, when the brain is considered at rest. The abnormalities don't always present themselves, however, resulting in a nearly 30% misdiagnosis rate.

Biomedical engineering professor Sri Sarma and neurologist Khalil Husari have developed an EEG analytics algorithm that uses at-rest data to build a "heat map" of a patient's brain activity that a doctor can then quickly and definitively interpret.

"Our tool looks for pathological connections in the brain that persist during resting state and thus can identify when a patient is more likely to have epilepsy even when the EEG looks normal to clinicians," Sarma says. "[The tool] has the potential to reduce misdiagnosis rates to under 10%," she adds.

Sarma and Husari plan to use a grant from the Louis B. Thalheimer Fund for Translational Research to perform a study of 200 patients to validate the algorithm's accuracy and customize another algorithm that removes excess brain activity from the heat map. Johns Hopkins Technology Ventures is seeking a patent for the technology.

— DANNY JACOBS



LOWER-COST CATARACT REMOVAL 3

More than 94 million people around the world — most living in low- to middle-income countries — suffer vision impairment or blindness due to cataracts, which are caused by clouding of the eye's lens. Unfortunately, the equipment needed to remove the clouded lens and insert a new one is prohibitively expensive to many people living in underresourced settings.

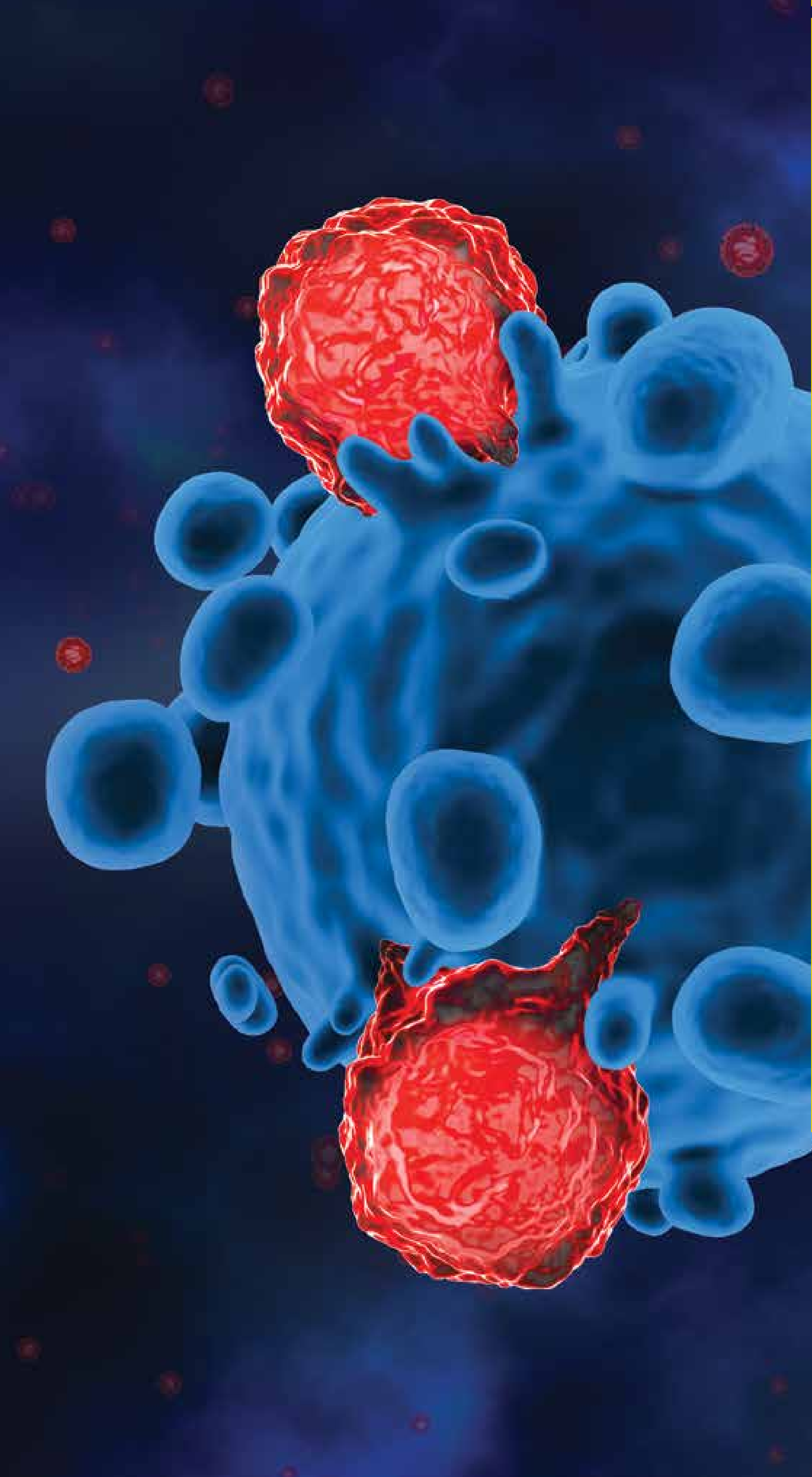
Kunal Parikh, a faculty member in the Department of Biomedical Engineering's Center for Bioengineering Innovation and Design and the Center for Nanomedicine at the Wilmer Eye Institute, is part of a team that is developing a low-cost hand-held device for cataract surgery that allows for fragmentation and removal of all grades of cataracts through a very small incision, giving patients in all settings access to optimal surgical outcomes.

"This device has potential to enable zero-energy fragmentation and removal of even advanced, mature cataracts to provide optimal outcomes for all patients in a time- and cost-efficient manner," he says.

Parikh's team includes ophthalmologists Samuel Yiu and Nakul Shekhawat, as well as Namratha Potharaj and Joshua de Souza, CBID assistant research engineers. The technology will be developed with support from the Alliance for a Healthier World, the Cohen Translational Fund, and the National Science Foundation.

— LDE

TECH TOOLS



Less Costly Couriers

A new particle assembly technology created by Johns Hopkins engineers in partnership with experts from a biotechnology company is making it easier and more cost-efficient to produce viral vectors: engineered viruses that have been used to modify therapeutic cells to treat congenital and acquired diseases.

A team led by Hai-Quan Mao, professor of materials science and engineering and of biomedical engineering, and associate director for the Institute for NanoBioTechnology, in collaboration with scientists from bluebird bio, has developed shelf-stable and size-controlled DNA particles that not only improve the quality and consistency of viral vectors but also their yield.

"Viruses are experts at targeting and infecting specific cells, and viral vectors take advantage of this, but producing them is time-consuming and costly," Mao says. "This work represents a great example of how we can partner with corporate collaborators to accelerate the translation of discoveries on the bench to the industry."

Team members believe the new technology will find a wide range of applications in the manufacture of a variety of viral vectors for gene and cell therapy applications.

— GINA WADAS

This particle manufacturing technology improves production of lentiviral vectors, used to generate CAR T cells (red) that recognize and kill cancer cells (blue) in patients.


artificial

"You click on the link that says 'cute cats,' and that opens the doorway for someone to take over your computer."

6/7/21
Anton Dahbura, PhD '84, Institute for Assured Autonomy, on CBS Baltimore, on the spate of ransomware attacks, including on Baltimore County Public Schools, that occurred in spring 2021.

"We have bigger hurricanes. We have longer heat waves. It's a challenge for us, as structural engineers, to keep up with those changing demands."

7/29/21 CNBC
Ben Schafer, Willard and Lillian Hackerman Professorof Civil and Systems Engineering and director of the Ralph S. O'Connor Sustainable Energy Institute, commenting on the physical demands on structures caused by climate change.

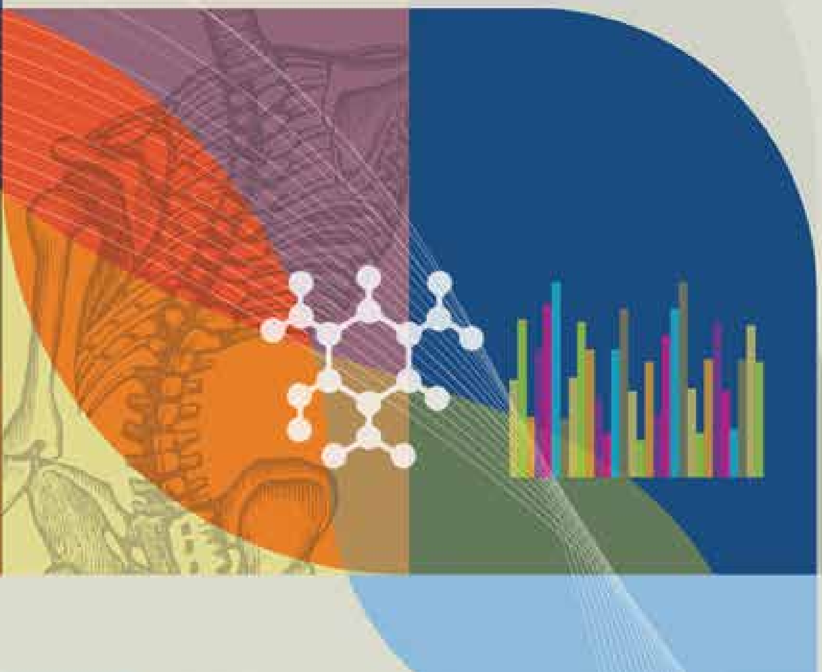
"You're not only now burning wood. You're burning heavy metals, and you're burning plastics and other things that wouldn't burn just in a forest fire."

7/22/21
Peter DeCarlo, Department of Environmental Health and Engineering, in *Los Angeles Times*, on the health risks posed by smoke from wildfires ravaging the west coast of the U.S. and parts of Canada.

"There's basically an entire human chromosome that had gone missing."

7/23/21
Michael Schatz, Bloomberg Distinguished Professor of Computer Science and Biology, in *The New York Times*, reflecting on the 8% of the human genome that was still missing back in 2013, now that scientists say they have completed the project.

Tissue Engineering: THE FUTURE is HERE



Through advances in biomaterials, stem cell science, and more, researchers are moving tantalizingly close to regenerating damaged body parts, creating new organs, and equipping our existing tissues to fight off debilitating diseases.

by KAREN BLUM
Illustrations by GORDON STUDER

Imagine if after a serious accident, your damaged facial bones could be replaced with tissue made by your own cells. Or if you could pop a pill that could reprogram your immune system to fight a chronic disease, freeing you from a lifetime of medications. While both prospects sound futuristic, scientists and engineers at Johns Hopkins and elsewhere are working toward these and other advances in tissue engineering.

Some researchers are creating novel biomaterials that can be transplanted into the body to serve as replacement parts or to encourage new tissue growth. Other scientists are developing small replicas of human tissues or organs that not only can be used to study the impact of novel drugs or treatments but also be encouraged to communicate with replicas of different organ systems. Still others are focused on using a new avenue known as immunoengineering to reprogram the immune system to tolerate organ and tissue transplants and medical devices, and using regenerative immunotherapies to direct tissue reconstruction.

"Some ideas always seem like science fiction before they become science fact," says Joshua Doloff, an assistant professor of biomedical engineering and of materials science and engineering. "That's just to help increase imagination and creative thinking, and eventually you tackle a really difficult problem."

In the roundup that follows, we highlight some of the most promising projects now underway at Johns Hopkins.

Bone and Facial Reconstruction

Patients experiencing craniofacial bone loss resulting from trauma or cancer removal surgeries have a few options today for reconstructive surgeries. But they all have limitations. Autografts, a process that involves taking a piece of bone from another body part to transplant to the face, create a second defect. Allografts (which use donor tissue) hold the potential for disease transfer or rejection. Surgeons also can employ materials like metals to serve as an implant; these, too, are subject to possible rejection and don't move like native tissue.

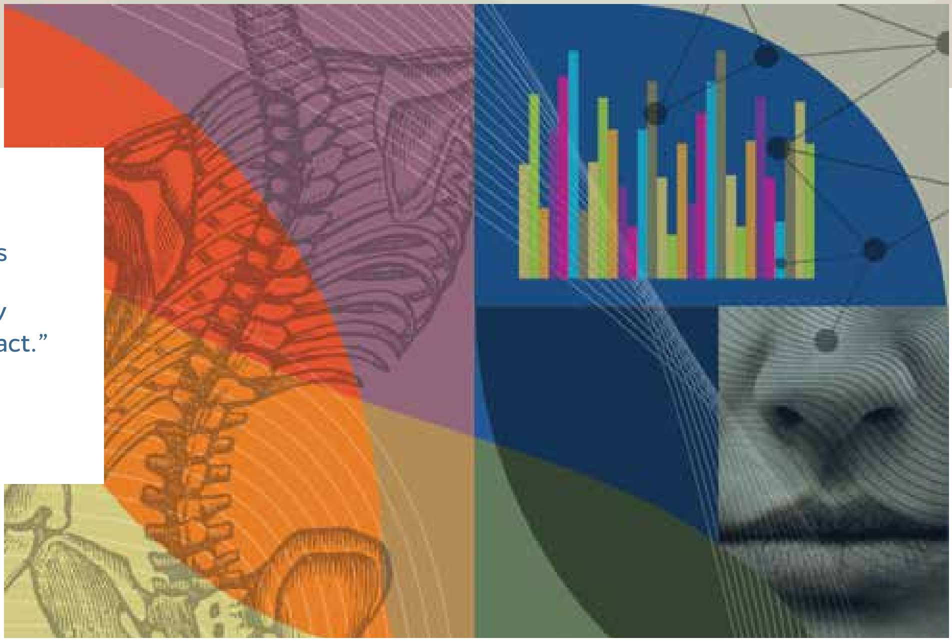
Enter Warren Grayson. The professor of biomedical engineering has been leading efforts to regenerate bonelike tissue with natural anatomical structure: living tissue that grows and changes with the patient and is made from a patient's own genetic material so it won't be rejected.

In studies in mice and pigs, Grayson's lab has used 3D printers to create scaffolds made from biodegradable polymers combined with other natural materials in the exact shape of the facial defects. Then, they take stem cells derived from fat tissue and apply them to the scaffold in a liquid solution. The idea is the cells will grow throughout the porous scaffold, which provides instructive cues so the cells form bone. The scaffold then degrades, leaving new, vibrant bone tissue.

Over the years, the Grayson lab has tinkered with various scaffold materials, methods to stimulate stem cells, and recipes for optimal bone growth. Animal studies have demonstrated that some bone can be

"Some ideas always seem like science fiction before they become science fact."

— JOSHUA DOLOFF



regrown in this manner. "There's definitely room for improvement," Grayson says, "but the results have been extremely promising. The data tell you that you can induce the body to go beyond its normal healing capacity."

In related work, Grayson and colleagues are applying similar processes to regenerate skeletal muscle and are developing new imaging tools to better study how these materials work once transplanted into the body. Grayson's group is applying for funding to conduct pilot clinical studies in humans. How quickly things move from there will depend on results and larger-scale clinical trials.

ON THE HORIZON: Growing replacement facial bones in the lab for transplant to humans

TIMETABLE: 3 to 5 years, for clinical studies

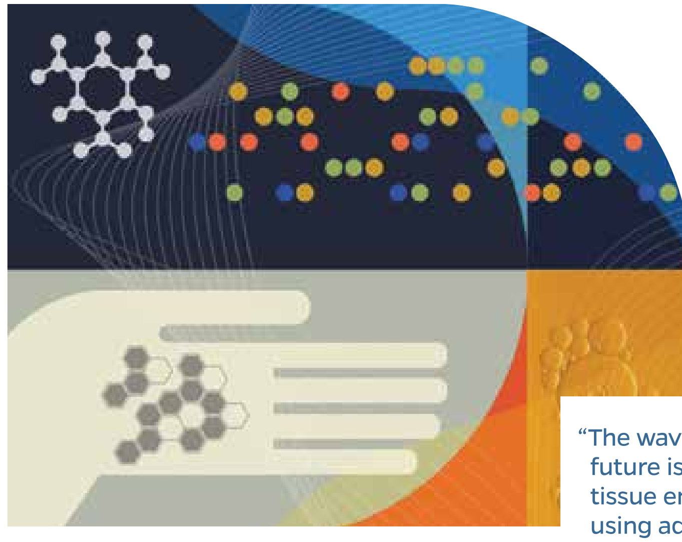
Cellular-Level Technologies

The human body holds trillions of cells that function like tiny computers, processing inputs that direct them to grow, divide, specialize, or self-destruct, explains Jordan Green, professor of biomedical engineering.

Green's lab has taken a cue from viruses — which trick cells into letting them enter and then use this space to replicate — to develop novel biodegradable nanobiomaterials that can deliver medications or genetic material in miniature packages (1/1,000th the size of a human hair) directly to specific types of cells, thereby reprogramming them from the inside out.

The process could be used to deliver DNA and RNA to cells to turn genes on or off individually or in combination. This holds potential for common genetic conditions, such as cystic fibrosis or hemophilia, as well as more complicated diseases, like cancer or diabetes, Green says. It even can help hit targets traditionally seen by pharmaceutical companies as "undruggable."

Green and colleagues also are working on developing different sizes and shapes of artificial immune cells to mimic biological cells, with proteins added to the surface that teach native immune cells what to do, such as attack cancers or promote tissue repair. A recent study demonstrated that lab-developed nanoparticles using molecules called poly(beta-amino ester)s, along with an engineered sequence of DNA, could reprogram liver cancer cells to secrete a protein called TRAIL that initiates cancer cell death. Combining this approach with small-molecule drugs could offer a new potential approach for cancer treatment.



"The wave of the future is doing in situ tissue engineering using administered gene therapy and immunotherapy to promote healing and regeneration of tissues within the body," Green says. "We're going to see these technologies more and more."

ON THE HORIZON: Gene therapies, stem cell therapies, and immunotherapies that can deliver treatments, promote tolerance to foreign bodies, and promote healing

TIMETABLE: 5 years for gene therapies and vaccines; 5 to 10 years for stem cell therapies

"The wave of the future is doing in situ tissue engineering using administered gene therapy and immunotherapy to promote healing and regeneration of tissues within the body. We're going to see these technologies more and more."

— JORDAN GREEN

Soft Tissue

People who have lost soft tissue, whether as the result of a congenital disease or due to trauma or cancer surgery, present a challenge to surgeons. Doctors can transplant fat tissue harvested from elsewhere in the body, but without supporting blood vessel networks, the transplanted fat tends to die over time. Some patients don't have enough soft tissue to spare for the transplant, and synthetic materials, such as silicon gels used in breast implants, can induce foreign-body reactions by the immune system.

Ideally, says Hai-Quan Mao, professor of materials science and engineering and of biomedical engineering, "You want the material to be porous enough to allow host tissue to grow into it but also retain its shape and the integrity of the repair site, and not lead to scarring and fibrosis by host immune cells. This concept is easy to understand, but it was difficult to come up with a material design to meet all of those requirements simultaneously."

Mao's team, working with Johns Hopkins plastic and reconstructive surgeons Sashank Reddy and Justin Sacks (now at Washington University in St. Louis), has invented a new type of synthetic soft tissue substitute that is well-tolerated and encourages the growth of soft tissue and blood vessels.

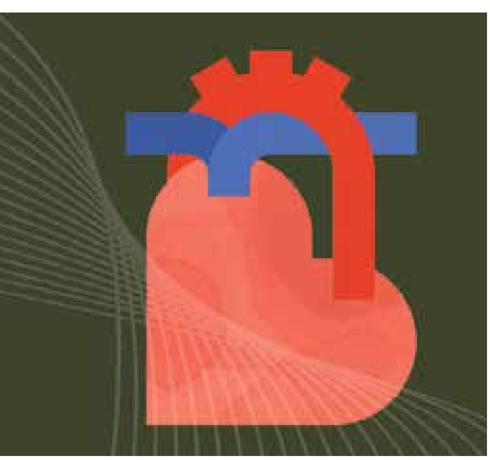
As a model, researchers observed the microscopic structure of fat, consisting of large cells clustered around an extracellular matrix that provides shape and stability. To devise a new biomaterial, they used a hydrogel made of hyaluronic acid — a naturally occurring component of the body's extracellular matrix and an ingredient found in more than 90% of cosmetic dermal fillers used in this country. Then, they incorporated nanofibers of polycaprolactone, the same material used in some resorbable sutures, to help the material retain its shape. They broke the fibers into short segments before making the composite gel to ensure easy injection through a needle. The resulting composite gel performed well in several animal studies, repairing deformities while encouraging growth of new blood vessels.

Mao and his co-investigators founded a company called LifeSprout that is conducting phase 1 clinical trials of small amounts (1 to 3 cubic centimeters) of the soft tissue substitute in the face for removing wrinkles or adding volume to a facial structure, before developing a strategy for larger-volume repairs.

They have been awarded a Maryland Stem Cell Research Fund grant to test this material for larger-volume repair, to see if they can speed and enhance regeneration by adding fat tissue-derived stem cells.

ON THE HORIZON: Injecting soft tissue material to fill in defects and combining donor stem cells from a bank or stem cells taken from a patient's fat tissue with synthetic soft tissue material for repair

TIMETABLE: 5 to 6 years, to allow time for regulatory approval



Heart

Deok-Ho Kim's research in cardiac tissue engineering is out of this world. Kim, an associate professor of biomedical engineering, has developed 3D engineered cardiac tissues that mimic the microarchitecture and function of human heart tissue on a microchip.

The work made news headlines in March 2020, when Kim and colleagues sent some of their miniaturized heart tissues with SpaceX to the International Space Station for a month to study how space travel and weightlessness — which has been known to simulate accelerated aging — affects the heart's structure and function. Kim's team observed that contractile force and heart function declined compared to similar tissues studied on Earth.

Sponsored by the National Institutes of Health and NASA, the team now is gearing up for a second space launch in fall 2022. This time, the engineered heart tissue chips will be treated with some type of drug compound or mechanical stimulation (muscle conditioning) to see if diminishing function can be prevented or lessened. The lab has been testing various interventions using a desktop-sized random positioning machine that simulates microgravity. A companion project funded by NASA is focused on monitoring how radiation from the sun and other elements in space impacts changes in human cardiac tissues.

In other work, Kim, David Kass (professor of medicine and biomedical engineering), and their colleagues are validating 3D engineered muscular tissues as a "clinical trial on a chip" platform to study cardiac and skeletal muscle deficiencies in human Duchenne and Becker muscular dystrophies, inherited conditions marked by progressive muscle weakness. By placing these patients' induced pluripotent stem cell-derived muscular tissues in multiwell plates in the lab, investigators will simulate clinical trials of a novel drug for muscular dystrophy, assessing toxicity profiles, helping determine appropriate doses, and potentially personalizing therapy for patients. This avoids typical problems experienced with clinical trials, such as patient recruitment, patient dropout, and harmful side effects.

A platform of heart and skeletal muscle tissues to test new drugs already is commercially available through Curi Bio, a company Kim co-founded in 2015.

In separate studies, Leslie Tung, professor of biomedical engineering, is using engineered heart slices to study electrophysiological conditions related to heart disease, such as arrhythmogenic cardiomyopathy, a cause of sudden cardiac death. His team seeds human induced pluripotent stem cells from patients onto a scaffold of slices of heart tissue from rats or pigs that have been stripped of their native cells. This serves as a model system to study heart arrhythmias and their potential treatments in the lab.

ON THE HORIZON: New treatments or therapies to help protect astronauts' health on long missions, treat age-related heart diseases, or electrophysiology conditions

TIMETABLE: To be determined

The team has filed a provisional patent on its work under a spinoff company named Innerva. With a few funding sources — including $10,000 from the 2021 national Lemelson-MIT Student Prize competition for collegiate inventors and $85,000 from the Johns Hopkins University Cohen Translational Engineering Fund — the team is continuing to refine the device.

Peripheral Nerves

A couple of years ago, Johns Hopkins plastic and reconstructive surgeon Sami Tuffaha approached Hai-Quan Mao with a vexing problem.

Tuffaha is an expert on targeted muscle reinnervation, a peripheral nerve repair procedure for amputees during which each severed nerve at the amputation site is sutured to a smaller motor nerve in a neighboring muscle. This helps prevent the disorganized growth of nerve stumps into painful tumors called neuromas. However, the size difference between the two nerve stumps being connected creates additional technical challenges and still leads to neuroma development in some 30% of patients.

Three engineering undergraduate students stepped up to find a solution. Under Mao's direction, Michael Lan '21 (BME), Bruce Enzmann (MatSci) and Anson Zhou (BME) devised a flexible, cone-shaped device as a conduit to guide proper nerve growth over the different-sized nerves.

Similar to a simple funnel, the biodegradable device has an outer porous, extendable, cone-shaped synthetic polymeric conduit filled with a biodegradable gel. The team created the conduit by spinning a polymer solution into a nanofiber mesh under a high-voltage electrical field. The mesh was then molded into a cone shape. The ends of the conduit can easily be sutured to the two nerve stumps. The students filled the inside of the conduit with a biodegradable hydrogel that included a nerve inhibitor to reduce nerve growth and shrink nerve size as it grows through the conduit. Together, these components guide and regulate proper connections between the two nerve stumps.

The COVID-19 pandemic didn't slow down this team. With a new member, third-year student Juan Diego Carrizo (MatSci), they continued to work together via Zoom and prepared the prototype devices in a temporary space set up by the team. In pilot studies in rats — conducted by medical student Erica Lee in the Tuffaha group — the team observed the device achieved a tapered shape of regrown nerve within the device. It also prevented neuroma formation and generated fewer pain fibers compared to the TMR procedure itself.

The team has filed a provisional patent on its work under a spinoff company named Innerva. With a few funding sources — including $10,000 from the 2021 national Lemelson-MIT Student Prize competition for collegiate inventors and $85,000 from the Johns Hopkins University Cohen Translational Engineering Fund — the team is continuing to refine the device.

ON THE HORIZON: Lan, Enzmann, Zhou, and Carrizo will be working with Johns Hopkins Technology Ventures to work through their next steps toward additional preclinical and clinical testing and commercializing the device.

TIMETABLE: An estimated 5 to 7 years until clinical use

"If we didn't have blood, we'd be 1 millimeter in size. The only reason we can be large, multiorgan organisms is because we have some sort of system that can move oxygen around the body to communicate among different organs."

— FEILIM MAC GABHANN

Vasculature

Feilim Mac Gabhann likes to ask his students to name the human body's most important organ. The usual suspects emerge: heart, brain, occasionally skin. But it's a trick question. In Mac Gabhann's eyes, it's blood.

"If we didn't have blood, we'd be 1 millimeter in size," says Mac Gabhann, associate professor of biomedical engineering. "The only reason we can be large, multiorgan organisms is because we have some sort of system that can move oxygen around the body to communicate among different organs."

Most people are familiar with the blood vessels they can see in their arms or their feet, he says. These vessels, like interstate highways, carry blood to smaller and smaller branches supporting all tissues in the body. Any given piece of tissue is packed with networks of tiny blood vessels, 1,000 times thinner than those we can observe.

Currently, some larger vessels that become injured or diseased, such as in the leg or heart, can be surgically repaired or bolstered, or replaced with synthetic materials. Patches of damaged skin can be repaired through skin grafts. Growing large amounts of tissue or thicker tissues, however, would be "a major next step," Mac Gabhann says, and requires creating the right environment to encourage blood vessel growth.

Mac Gabhann's lab has been using computational modeling — the application of computers to simulate and study complex systems — to study vascular endothelial growth factor, a protein family heavily involved in blood vessel growth and development. The lab's members want to know why and how these proteins direct the growth of varying blood vessel networks supporting different areas of the body. "If we can understand that," he says, "we can turn it into a forward engineering problem and design the signals we need to get the kind of networks we want."

He's looking primarily at two areas. One is skeletal muscle, working to develop a medical intervention that could help people with peripheral artery disease, a form of blockages of blood vessels in the leg that make it painful to exercise. The other is developmental biology, attempting to understand how blood vessel networks behave in growing tissues.

ON THE HORIZON: Increasing the size and complexity of tissues that can be derived from stem cells; creating 3D organs from a person's own cells or from donor cells that are compatible or that could be altered through gene editing tools

TIMETABLE: 10 years

Pancreas

Joshua Doloff's lab explores the intersection between therapeutics and living systems, with a goal of understanding what happens when new materials are introduced into the body and how the host immune system behaves and perceives them. An implanted glucose monitor functioning as an artificial pancreas for those with diabetes, for example, can be attacked by the body as foreign. This can lead to the development of scar tissue around the device, diminishing its function.

Implanting devices can create a one-two punch for the immune system, Doloff notes. Doctors want to deliver grafts correctly to restore function, but if they're implanted in the midst of a chaotic autoimmune disorder, two immune challenges emerge: preventing graft rejection and modulating the immune system to prevent further damage. He's also pursuing immunoengineering studies to help prevent rejection of grafts.

In recent work, Doloff's team has demonstrated that loading implantable devices with a crystallized immunosuppressant drug that is slowly released at the local area can inhibit the immune response against those devices. The research team (not the lab) is also working on ways to encapsulate islet cells and transplant them into patients with diabetes, potentially to replace nonfunctioning pancreatic cells and eliminate the necessity for insulin injections or long-term immunosuppressant drugs needed with implanted devices and organ transplants.

"Over the past few years, we've gotten a lot of insights into foreign-body response," he says. "We can actually block biomaterial-specific responses quite effectively. And I'm confident that we can do that now for not just biomaterials but even multicomponent devices, such as glucose monitors." ■

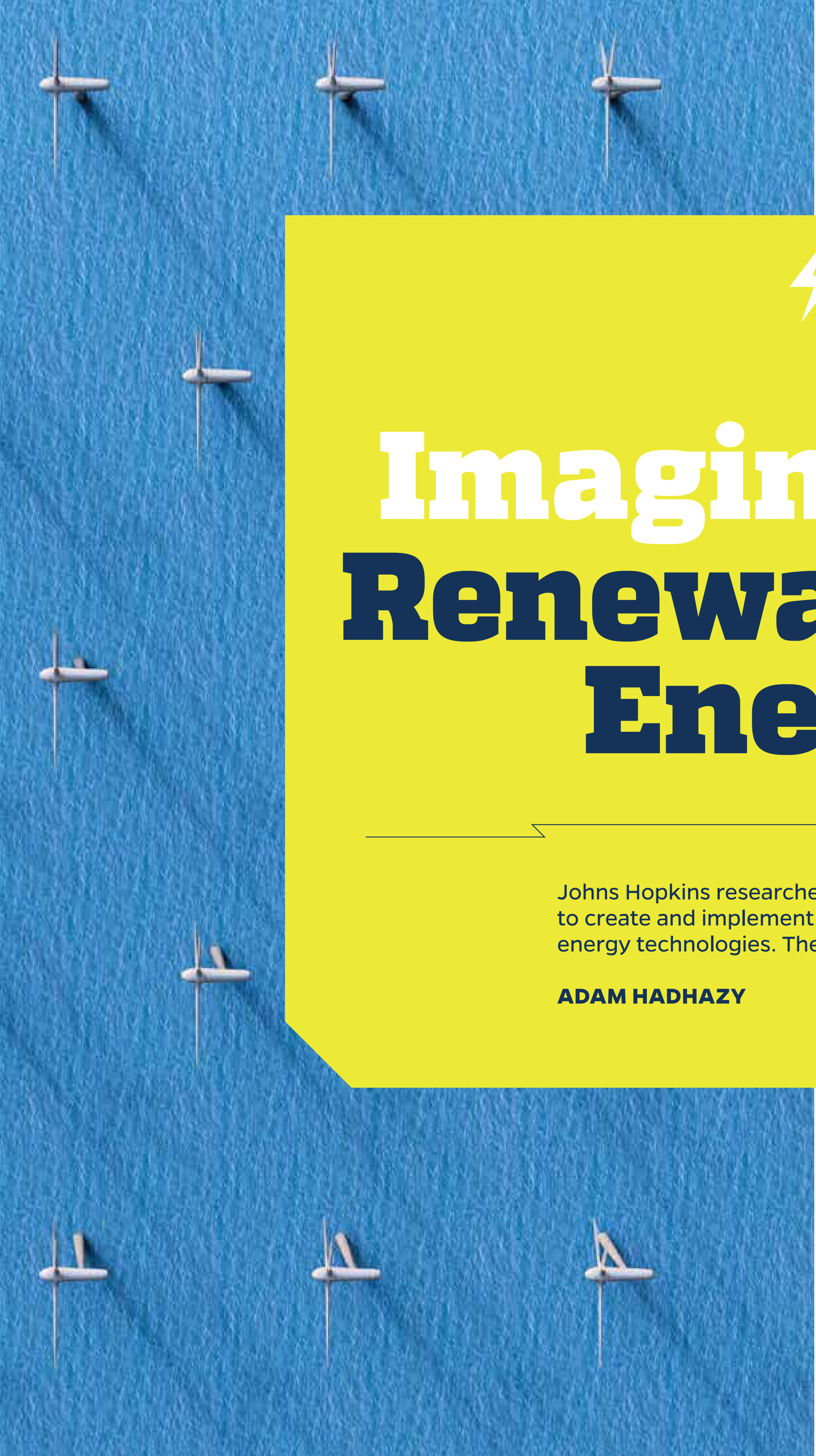
ON THE HORIZON: Medical implants that aren't rejected by the natural immune system

TIMETABLE: 5 to 10 years

In recent work, Doloff's team has demonstrated that loading implantable devices with a crystallized immunosuppressant drug that is slowly released at the local area can inhibit the immune response against those devices.

Harnessing the Immune System

The launch of the Translational Tissue Engineering Center at Johns Hopkins in 2010 laid the foundation for many of today's advances. Directed by biomedical engineering professor **Jennifer Elisseeff**, a pioneer in regenerative immunology, the center was founded as a joint venture between the Wilmer Eye Institute and the Department of Biomedical Engineering. In 2019, the university created the Johns Hopkins Translational ImmunoEngineering Biotechnology Research Center with a $6.7 million grant from the National Institutes of Health.



Re-Imagining Renewable Energy

Johns Hopkins researchers are on a mission to create and implement scalable, renewable energy technologies. There's no time to waste.

ADAM HADHAZY

The world is transitioning to clean, renewable, sustainable energy—and fast. Consider this: In 2021, more than 90 percent of all the new electricity generation added around the world came from renewables like solar and wind, according to the International Renewable Energy Agency.

To see how renewable energy is on a roll, look no further than Johns Hopkins University. After committing in 2008 to slash greenhouse gas emissions by 51% by 2025, the university is now set to hit that target a full three years early, thanks to a substantial investment in off-site solar energy.

Yet as heady as all that news is, it comes at a time of ever-increasing climatic peril. To wit, consider a multiple-choice question: Of the 10 hottest years on record, how many ccurred in the last 10 years? A) zero, B) one, C) five, or D) nine.

The answer — alarmingly — is D.

The fate of Earth's climate, and quite possibly that of modern, industrialized humanity as we know it, hinges on the far-bigger question of how many degrees our planet ultimately warms this century. Since 1880, the pumping of heat-trapping greenhouse gases (primarily carbon dioxide) into the atmosphere through humankind's burning of fossil fuels has already warmed the world by 1 degree Celsius (2 degrees Fahrenheit). The 2015 Paris Agreement set a goal of limiting the total rise to 2 C (3.6 F) above pre-industrial levels, while recognizing that the avoidance of climate change's most dire impacts means shooting for 1.5 C (2.7 F). Achieving either of these ambitious but critical goals mean somehow accelerating renewable energy's development and adoption far faster than even its current clip.

To help supercharge the ongoing energy transition, this past Earth Day, Johns Hopkins University and the Whiting School of Engineering announced the creation of the Ralph S. O'Connor Sustainable Energy Institute. Initialized as ROSEI and pronounced "rosy," the new institute serves as an interdisciplinary home at Johns Hopkins for ongoing research and education. In a multi-pronged approach, ROSEI is bringing technical researchers together with social scientists university-wide to create and implement scalable, renewable energy technologies.

"Embedded in the mission of the institute is trying to make things better for the world by focusing on a problem we're all facing now, which is the need for transitioning our energy use," says ROSEI Director Ben Schafer, who is the Willard and Lillian Hackerman Professor of Civil and Systems Engineering at the Whiting School.

The urgency grows greater by the day. In August, the United Nations-led Intergovernmental Panel on Climate Change, which has convened since the late 1980s, issued a new report authored by hundreds of international climate scientists. In some of the starkest language ever to appear in IPCC reports, the scientists wrote that it is "unequivocal that human influence has warmed the atmosphere, ocean and land." This warming is "already affecting many weather and climate extremes in every region across the globe," observable "in extremes such as heatwaves, heavy precipitation, droughts, and tropical cyclones."

"What's new in the latest IPCC report is that [climate change's] warming impacts are worse and happening faster than we thought," says Johannes Urpelainen, a ROSEI researcher and the Prince Sultan bin Abdulaziz Professor of Energy, Resources and Environment at the Paul H. Nitze School of Advanced International Studies. "We're already in a situation where we might blow past the 1.5 degrees Celsius mark in only 10 years, in the early 2030s. And that's scary. It means we need to urgently act."

A RENEWED PUSH FOR RENEWABLES

Schafer and Urpelainen are two of ROSEI's seven Leadership Council members, each of whom has contributed to bringing the institute to fruition and continues to guide initial investments.

ROSEI was made possible by a $20 million gift from the estate of trustee emeritus and alumnus Ralph S. O'Connor '51, and will serve as the catalyst of a new $75 million, 10-year total investment by the Whiting School and the university in energy-related research and education.

An entrepreneur, civic leader, and philanthropist, O'Connor gave generously to Johns Hopkins for decades, providing financial aid, endowed faculty chairs, athletics, art, awards for undergraduate entrepreneurs, and facilities. Tying in with ROSEI's mission, a Homewood campus recreation center named after O'Connor is part of the largest solar installation on campus, boasting nearly 1,400 solar panels on its roof and that of the adjacent Newton White Athletic Center.

Besides the Leadership Council, an initial slate of 26 faculty members is affiliated with ROSEI, collectively bridging a rich array of disciplines. Expanding its expertise and influence, ROSEI will also partner with other Johns Hopkins divisions, including the Applied Physics Laboratory, the Bloomberg School of Public Health, and the School of Advanced International Studies, as well as government agencies in the Washington, D.C., area.

Schafer explains that ROSEI is organized so that roughly two-thirds of its resource allocation and activities will center on enabling technologies for renewable energy. Within that realm, wind and solar are the primary areas for ROSEI faculty members, along with transforming conventional fossil fuel use. The remaining one-third of ROSEI's overall efforts will center on equitable implementation, zeroing in on the energy policy, marketplace development, and education that will need to happen for sustainable energy to successfully turn the tide against climate change.

"We're trying to attack the full breadth of the problem," says Schafer.

"ROSEI is a unique way for Johns Hopkins to lead in addressing the challenges in sustainability in an interdisciplinary way," says Chao Wang, associate professor of chemical and biomolecular engineering, and an affiliated researcher in ROSEI. "We want to be very synergistic, taking advantage of what people here on campus are good at."

Susanna Thon, associate professor of electrical and computer engineering, and a member of the ROSEI Leadership Council, adds, "We're reimagining renewable energy at Johns Hopkins by connecting all these researchers together and building something bigger than the sum of its parts."

CAPTURING THE SUN'S BLAZE

For their part, Thon and her group at Johns Hopkins are looking to revolutionize today's solar power by expanding the range of light it can collect and where its energy-reaping cells could go. The solar story so far has been one of great success, surging from about 1 gigawatt of capacity worldwide in 2000 to knocking on the door of 1 terawatt (1,000 gigawatts) today. (One gigawatt is enough to power approximately 250,000 average homes.)

That said, solar has significant room for improvement. For instance, conventional, photovoltaic solar power — provided by those rigid, blue-grayish panels arrayed in fields and on rooftops — has relied on the element silicon. As a semiconductor, silicon absorbs sunlight and transfers some of its energy to particles called electrons, the flow of which comprises electricity. The widely available commercial panels of today possess solar cells with about a 20% efficiency rate, meaning they convert 20% of the sunlight that strikes them into usable electricity, with much of the rest lost as heat. Even with anticipated advances, however, the theoretical maximum for conventional silicon cells tops out around 30% efficiency. "We're close, and that's it for silicon," says Thon. The

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– Ben Schafer

JOHANNES URPELAINEN

BEN SCHAFER

CHAO WANG

DENNICE GAYME

CHARLES MENEVEAU

SUSANNA THON

efficiency of traditional solar panel also drops precipitously for light coming in at angles.

Thon's group at Johns Hopkins is looking to address both issues. A key approach is manipulating materials at the nanoscale level, at mere billionths of a meter, in order to produce novel properties. For instance, so-called quantum dots — nano-specs of semiconductor material — can be grown to differing sizes and arranged to capture more colors of sunlight than bulk silicon, thus reaping energy more efficiently.

Another approach along these lines is to devise solar cells that only absorb infrared light but let visible through. Panels made of this material would be nearly invisible and thus could go right over windows, greatly expanding places where solar generation can occur. One such place is glazing windows, especially of cars, trucks, and other transportation vehicles, which are still dominantly powered by fossil fuels and represent a tremendous source of global carbon emissions.

Thon and her close colleagues are collaborating with other engineers and chemists across the university to realize all this potential. "I've already met lots of people at other schools at Johns Hopkins through ROSEI," says Thon, "and it's much easier when you have this entity that forms these natural connections."

REAPING THE WIND

Like solar, wind power has also done smashingly. Only around 20 gigawatts of capacity were in place worldwide in 2000, and with well over 700 gigawatts currently installed, according to the Global Wind Energy Council, wind is likewise knocking on terawatt's door. Both generation technologies have plummeted in cost per watt and are now cheaper than traditional coal-fired and natural gas-fueled power stations.

At the heart of wind power is the turbine, usually a vertical pole with three affixed blades. When it comes to engineering individual blades and stand-alone turbine units, wind power technology has already been highly optimized, says Charles Meneveau, the Louis M. Sardella Professor of Mechanical Engineering at the Whiting School and an affiliated faculty member at ROSEI. Turbines keep getting bigger and more powerful, with the world's largest soaring over 800 feet tall, in shouting distance of the approximately 1,000-foot-tall Eiffel Tower. Regarding today's colossal turbine, "imagine an Eiffel Tower that moves," says Meneveau. Blades can run nearly the length of a Boeing 737, whip around close to 200 miles per hour, and sweep out an area the size of several football fields.

While bigger and more turbines equate to more power, there remains serious untapped energy-generating potential in better understanding the dynamics of how turbines in vast farms influence each other, as the incoming winds and other meteorological conditions inevitably vary. "We're talking about gigantic machines interacting with the environment at scales we're not used to," says Meneveau. "I think we've just started scratching the surface of a lot of improvements."

Meneveau's specialty is studying hydrodynamic turbulence, that which occurs in wind farms as a gust flows through a lead turbine's blades, is weakened, and then flows through another nearby turbine. Meneveau and colleagues computationally model this fluid mechanical complexity, and their findings have already advanced turbine array arrangement designs. A new goal of the ongoing research is to democratize the information, Meneveau says, by making not only the results and insights publicly accessible but also the full-scale simulation data themselves. "We're working on distributing outstanding data and analysis to the world," he says.

A close colleague of Meneveau's in these matters of maximizing wind energy is ROSEI Leadership Council member Dennice Gayme, associate professor of mechanical engineering and the Carol Croft Linde Faculty Scholar at the Whiting School.

Gayme focuses on understanding the impact of turbulence, atmospheric flow, and designing wind farm control and grid integration strategies to ensure that the wind farm efficiently delivers steadier, predictable, and more usable power to the electrical grid. Computational models that Gayme, Meneveau, and colleagues have recently developed can more accurately predict the power output from farms, thus optimizing turbine placement in the design stage. They have also shown that dynamic models that take these factors into account enable wind farms to participate in grid services. Gayme is also looking to build models that incorporate more forecasting to understand power output potential and improve real-time adjustments of turbine operations.

Furthering their work, Gayme and Meneveau have received a grant through ROSEI to model the effects of the motion imparted to turbines as waves roll through offshore wind farms. The upshot should be performance gains that really add up over years of energy production. "This research is at the cutting edge of using mathematical tools to better understand variability in the environment," says Gayme.

FINDING SUSTAINABILITY IN THE UNSUSTAINABLE

For all the progress renewables have made — and will continue to make, courtesy of the advances pursued by ROSEI researchers — fossil fuels will assuredly remain humanity's primary sources of electricity generation and transportation fuel for years to come. Accordingly, a major thrust at ROSEI is developing technologies that curb fossil fuels' impacts.

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– Susanna Thon

"Fossil fuel use is going to be around for a while still," says Schafer, "so we need technologies that help take away the danger and actually make something useful for us."

Wang, the ROSEI-affiliated chemical engineer, is spearheading multiple efforts toward this end. One focus is on the capture of carbon dioxide from air, followed by conversions into value-added products. His group is developing novel thermo- and electrochemical technologies to enable direct air capture, or DAC. The technology features the use of Earth-abundant materials, robust acid-base chemistries, and renewable but intermittent energy sources, such as solar and wind electricity. By substantially improving the energy efficiency, Wang's group is targeting DAC at costs lower than $100 per metric ton of captured carbon dioxide, a threshold for commercial implementation.

Rather than storing captured carbon in underground reservoirs, as has been widely proposed, Wang's group is also exploring how to cost-effectively convert the captured carbon dioxide into useful products, such as chemicals, fertilizers, and structural materials. "There are a lot of things we're working on with carbon-based chemicals and materials," says Wang. "Our ultimate goal is to fix the carbon for a long lifetime so that we can offset the trend of accumulating carbon in the atmosphere."

In a similar vein, Wang's group is conducting research into catalytic upcycling of end-of-life plastics. The concept: Convert solid waste plastics into liquid feedstocks for useful chemicals — essentially what the petrochemical industry already does, but in reverse. "Discarded hard plastics can be a source of hydrocarbons, just like crude oil," says Wang. "The difference is one source is solid, the other is liquid."

Wang's group is focused on low-quality, valueless plastic wastes — #3–7 mixtures, including grocery bags and packing peanuts — that hardly ever get recycled and accordingly end up in landfills and in the ocean, where they cause contamination to soil, water, and wildlife. The researchers already have demonstrated how these plastics, even when mixed up with regular household food trash and yard waste, can be readily transformed into aromatic compounds such as xylene, which has high industrial value. The group now plans to set up a pilot facility in Chao's lab on Johns Hopkins' campus to process 1 kilogram a day of plastic waste. In parallel, talks are underway with Maryland authorities and local waste management companies about establishing a pilot plant off Johns Hopkins' campus to process 1 ton per day, starting perhaps as soon as next year.

"We've already done the fundamental science," says Wang. "Now we're pushing toward commercialization."

INTO THE REAL WORLD

Getting renewable and sustainable energy technologies, like Wang's plastics upcycling, out of the lab, into the real world, and scaled up in an equitably beneficial way is the second major thrust of ROSEI. Urpelainen is a key player in this regard. He brings his expertise in energy policy research and international issues relating to climate change and the transition to renewable energy.

"ROSEI has a strong technical foundation but also has a clear interest in broader issues in society, like equity and feasibility of implementation," says Urpelainen. "Our purpose is, 'How do we take these wonderful technologies we're developing and use them to encourage sustainable energy production and consumption across the global energy system?'"

The implementation challenge is multifaceted, from gaining social acceptance and government support to developing markets where interested parties are incentivized to build out renewable energy — especially of the inventive, reimagined technologies ROSEI's researchers will have to offer.

Befitting the enterprising spirit of the institute, ROSEI will initially operate out of the second floor of FastForward R. House, a Johns Hopkins Technology Ventures innovation hub near the Homewood campus.

"Through ROSEI, we will have sustainable, energy-related activities and efforts across all levels, from high school outreach to our undergraduate and graduate students, and from our postdocs and research scientists to young faculty and senior faculty," says Schafer.

As part of broadening academic opportunities at the university, Johns Hopkins is boosting energy-related curricula, including a potential minor program in energy. "The university is showing a commitment to attracting the best students," says Thon, "and the current students are thrilled about the new academic resources that will be available to them."

ROSEI-affiliated faculty members have seen firsthand how the intertwined topics of renewable, sustainable energy, and the pan-national, generational fight against climate change resonate with their students. "It's the critical challenge of our world," says Thon.

"Our students are getting more and more interested in this area," adds Gayme. "That's why it's so important having a home for this research at Hopkins with ROSEI."

"For the students, it's so new and exciting," says Meneveau. "They have the sense that they might contribute to changing things for the better." ■

"WE'RE TALKING ABOUT GIGANTIC MACHINES INTERACTING WITH THE ENVIRONMENT AT SCALES WE'RE NOT USED TO. I THINK WE'VE JUST STARTED SCRATCHING THE SURFACE OF A LOT OF IMPROVEMENTS."

– Charles Meneveau


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Austin DiOrio, at APL

Doctor of Engineering Program Focuses on Practice

EARNING A DOCTORATE HAS ALWAYS BEEN PART OF THE PLAN FOR AUSTIN DIORIO, ME '10. While at MIT receiving his MS in aeronautics and astronautics in 2012, DiOrio passed the qualifying exams to pursue his PhD, but life, as it often does, got in the way.

For nearly a decade, marriage (and now parenthood) and a busy career at Johns Hopkins' Applied Physics Laboratory put his doctoral studies plans on hold. That changed last summer when DiOrio began work in the new Doctor of Engineering program, a collaboration between APL and the Whiting School of Engineering.

Created for midcareer individuals working full time and piloted with APL, the DEng program offers DiOrio the flexibility he needs. "When I first heard about the program, I thought it was too good to be true," says DiOrio, who works as an aerospace engineer in APL's Air and Missile Defense Sector. "APL has made it a lot easier to earn my degree while working. The partnership with the Whiting School makes it even better."

With a focus on practice and application versus preparing for a career in academia or research, the program allows APL staff to continue work on sponsor-facing research. APL also provides financial support and paid leave for students to attend classes and work on research. The program launched in 2018, and the first four graduates in the program earned their degrees last May.

"Getting my degree is still a balance between professional and personal life — I have a 2-year-old now — but this is not a nighttime degree. That's the point of this program," DiOrio adds.

The program, which requires a master's degree and is completed in three years, not the traditional five, is personalized to each student's interests and APL expertise. DiOrio has two Whiting School advisers in Mechanical Engineering — Jaafar El-Awdy and Ryan Hurley — and an APL mentor, Hasan Oguz. This semester, DiOrio is taking classes and developing his research focus.

"Rocket motor plumes cause damage to surfaces from heat and particles," says DiOrio, who works on thermal analysis at APL. "That's the problem I plan to solve and am working out details on my research plan now."

Bart Paulhamus, chief of APL's Intelligent Systems Center and newly minted DEng, has sage advice for DiOrio and any students in the program: "This program is not a sprint — it's a marathon. It doesn't let up. But it is very much what you make of it, and I am glad to have participated."

— SARAH ACHENBACH

THIS PAGE: CRAIG WEIMAN, JOHNS HOPKINS APPLIED PHYSICS LABORATORY.

A Patch to Catch Cardiac Arrest

JEFF KIM, A MASTER'S STUDENT IN ELECTRICAL AND COMPUTER ENGINEERING, WANTS TO IMPROVE the survival rates of people who experience a cardiac arrest while alone.

This started for Kim in 2016, when his uncle had a sudden and fatal heart attack while alone in his apartment. A couple of years later, Kim's grandmother also had a sudden cardiac arrest but was in a public location, where onlookers alerted first responders. She made a full recovery.

The contrast in outcomes stuck with Kim, especially after he learned that in the United States alone, there are more than 356,000 out-of-hospital cardiac arrests per year, 90% of which are fatal. He decided to tap into his experience as a hardware engineer to combat the problem and gathered two other engineers — Jihoon Han and Peter Kim, both students at Northwestern University — to start ResQ.

The ResQ team has created a cardiac patch that patients would wear throughout the day, continuously monitoring the strength and timing of their hearts' electrical activity (cardiac electrocardiogram signals). The data are then transmitted in real time to the patient's smartphone, which communicates directly with caregivers and physicians. If the device recognizes abnormal heart activity, it notifies caregivers to call for immediate help. Patients can also set up telemedicine appointments through the software platform, where they can consult cardiologists based on real-time or previously collected ECG data.

After putting their first prototype through a series of electrical and performance tests and trying the device on themselves, they found that it could record and transmit clean ECG data to the smartphone application. From there, the team made improvements to the data acquisition unit and the communication module to accelerate the data transfer protocol.

The ResQ team plans to test its second prototype with Sithu Win, an assistant professor at the University of California, San Francisco, to see if the device can capture patients' ECG data during exercise.

Kim credits Department of Electrical and Computer Engineering Associate Research Professor Israel Gannot's Design of Biomedical Instruments and Systems course with teaching him how to turn an idea into an actual business.

"The class taught me how to start a medtech company from ground zero, which was supplemented by Dr. Gannot's personal medtech entrepreneurship journey," Kim says. "I was able to reach out and consult with faculty members not only within the Whiting School but also at the School of Medicine, who were excited about the venture and willing to give feedback."

— **WICK EISENBERG**

Better Triage on the Battlefield

COMBAT TRIAGE MAY SOON UNDERGO A TRANSFORMATION, THANKS IN PART TO A TEAM of student engineers who helped develop a digital triage assistant.

Worn like a watch on soldiers' wrists, the device collects soldiers' vital signs and location data, feeding that information in real time to a dashboard that not only tells medics where the wounded are located but also assesses the severity of their injuries.

The student engineers collaborated on the project with the NATO HQ Supreme Allied Command Transformation Innovation Hub, the SACT Medical Branch, and Czech Technical University.

The student team's main innovation is a machine learning model that combines data gathered from wearables to calculate a mortality likelihood score for an individual soldier. The score will help combat medics quickly determine who should receive treatment first.

During their research, the students discovered that current battlefield triage comes down to a few simple assessments: Can the soldier stand up? Can they raise their hand? Are they able to yell, or are they unconscious? With very little data, combat medics must evaluate injuries and prioritize evacuation in the shortest time possible.

The students, all members of the A. James Clark Scholars Program, designed the digital triage assistant with an eye toward automating this process, getting the right information to medics as quickly as possible.

"We were surprised to find that medics decide if someone is on the next helicopter out based on just two or three factors," says David Calvo, a fourth-year computer science major. "That's born out of necessity — they can't afford to spend even a few minutes triaging a single soldier. But we don't have that limitation with a digital triage assistant. The system allows for continuous and real-time monitoring of vitals, and alerts the medic if a soldier's condition gets worse."

In addition to creating the mortality likelihood score, students built a maplike dashboard that uses multicolored dots to indicate each soldier's score and GPS location. The system also shares live triage updates with commanding officers at headquarters.

The first prototype was scheduled to be field-tested with the Armed Forces of the Czech Republic this fall.

The team is already thinking about how this system could move beyond the battlefield and have civilian applications, such as in busy emergency departments or following mass casualty incidents.

— CATHERINE GRAHAM

The A. James Clark Scholars Program, established in 2016 with a $15 million investment in the Whiting School from the A. James & Alice B. Clark Foundation, is designed to attract talented engineering students to Johns Hopkins and also to prepare them for leadership roles.

OPPOSITE PAGE: WILL KIRK/HOMEWOODPHOTO.JHU.EDU.

Women Mentors in STEM

Joanne Baek, left, with Elena Skarupski

JOANNE BAEK '22, WAS NERVOUS ABOUT CAREER PLANS AT THE START OF HER junior year. The Chemical and Biomolecular Engineering undergrad needed a mentor to help her navigate options and the challenges she faces as a woman pursuing a future in STEM (science, technology, engineering, and mathematics).

"Most of my mentors at the time were men," Baek explains. Then she heard about the student-created Womxn Mentoring Whiting, a new program at the Whiting School. Created by Rebecca Yu '21, BME and CS, and launched in fall 2020, the program pairs undergraduate students with with juniors, seniors, and graduate student and alumnae mentors in STEM disciplines.

"The fact that WMW is exclusively for women was really appealing to me," says Baek. "It became a safe space for me to talk to other women about concerns I would not have felt comfortable sharing with my male mentors."

The program aims to address ongoing issues of underrepresentation in the STEM workforce — women account for 27% of all STEM workers, according to the U.S. Census Bureau — with regular mentor/mentee check-ins and a robust hybrid program of social gatherings (such as game nights and fun competitions) and professional development opportunities (including a women engineers speaker series and presentations on post-graduation career options).

Yu, who is continuing her research with the Department of Biomedical Engineering's Rheeda Ali while applying to PhD programs in computer science, has big plans for WMW this year. New initiatives will include a focus on research opportunities and a mock interview/resume critique to prepare students applying for internships and jobs.

Yu says her Whiting School mentors, Ali and the Department of Biomedical Engineering's Natalia Trayanova, inspired her to found the mentoring program. "Male engineers tend to speak up a lot more and more often," Yu says of the program that began with 17 mentor/mentee pairs a year ago and has 40 pairs this semester. "It's easy to doubt yourself as a woman in engineering. Having the support of women who are confident in my abilities made me more confident."

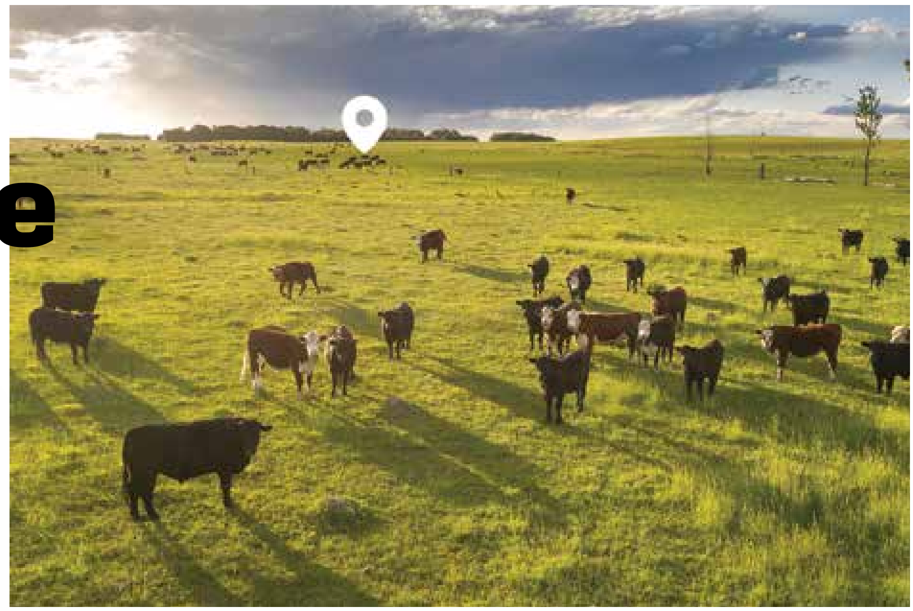
Baek says that her mentor, Rachel Shapiro, a third-year PhD student in ChemBE, helped Baek focus her decision to take a gap year before she pursues a PhD program.

Last spring, Baek began mentoring Elena Skarupski, ChemBE '23, who finds WMW's networking opportunities particularly impactful. "Getting involved in research for the first time was intimidating because I had no prior experience and cold-emailing lab PIs I'd never met was new [to me]," Skarupski recalls. "Joanne explained how to contact labs; hearing her experiences made the process seem more within reach."

— SARAH ACHENBACH

ALUMNI

Homing in on the Range



AS FOUNDER AND CEO OF ROPER, MAEVE GARIGAN '01, MA '08, AIMS TO REVOLUTIONIZE BEEF production with innovative technology — a GPS-enabled ear tag for cattle. "It's like a Fitbit for cows," she says. The tag allows ranchers to track the location and health of cattle over long distances, enabling them to better manage grazing, identify sick or distressed animals, and streamline recordkeeping.

"I was interested in working on technology specifically for rural and agricultural users because it is such an underserved market," she says.

Garigan, who grew up on a farm in the Willamette Valley in western Oregon, was a first-generation college student. As a mechanical engineering major, she worked on a project building an autonomous underwater vehicle and found that she loved exploring the unknown and solving real-world problems. "The experience of going to Hopkins pushed me to expand my own intellect and creativity in ways that shaped everything else that followed," she says.

After graduation, Garigan began a career in research and development working with elite military commands. Then, in 2017, while grieving the sudden death of two close friends, she left her job and embarked on a yearlong solo camping trip in the mountains of New Mexico. "I had this massive cleansing moment," she says.

Eventually, she decided to start her own company, with a focus on serving rural communities. With support from the New Mexico Small Business Assistance Program, she set up a working group with ranchers and listened as they shared their problems with tracking their cattle.

"That was the spark of it, and the rest of it unfolded from there," she says.

She created a product concept and then won a series of grants and prizes to fund the development of a new cattle-tracking device. In 2018, she founded Roper with former colleague and fellow Johns Hopkins alumnus Dana De Coster, MIPP '12, a retired U.S. Navy SEAL.

A recent pilot study showed that the tag works very well: It is lightweight and comfortable for the cow, as well as durable; it operates on ultralow power, with a small solar panel and battery; and it successfully transmits GPS location and activity data every hour for display on a mobile app.

Roper has filed multiple patents on its technology and is planning the commercial launch of its product in late 2021. "It's not just about having a great idea, but it's seeing the impact on other people's lives that is the most fulfilling," she says

— WILL HOWARD

Maeve Garigan

"It's not just about having a great idea, but it's seeing the impact on other people's lives that is the most fulfilling."

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Aaron Baughman with his two daughters

Using AI in New Ways

DURING THE WIMBLEDON CHAMPIONSHIPS, TENNIS TAKES PLACE ON 18 COURTS, WHILE MOST FANS WATCH one match at a time and then view preselected highlights later to catch up. To deliver highlights faster and more effectively, Wimbledon turned to Aaron Baughman's team at IBM, which developed AI Highlights. This new technology automatically processes live-streaming videos of tennis, relying on indicators such as crowd noise, commentator tone, and player gesture to measure excitement and then select video segments to highlight.

As a Master Inventor and distinguished engineer at IBM, Baughman, MS '07, creates AI-based experiences such as this for the U.S. Open, the Masters Tournament, ESPN fantasy football, the Grammy Awards, and others — work that, in turn, has led to some extraordinary real-life experiences.

"I've been able to go into the ESPN studios and meet celebrities such as Matthew Berry, Sage Steele, and Baron Davis," he says. He has also competed directly against NFL football players such as Eli Manning in celebrity fantasy football leagues.

After completing his bachelor's degree in computer science at Georgia Tech, Baughman worked for U.S. classified government agencies on biometrics (face, iris, and fingerprint) while completing a master's degree in computer science at Johns Hopkins. He was able to craft his own curriculum and include courses in applied biomedical engineering. "The cross-disciplinary aspect of the Johns Hopkins education is very unique," he says.

In 2011, he began working on the *Jeopardy!* (Watson) project at IBM. The question/answering computing system was initially developed by IBM to win at *Jeopardy!*, but the broader aim was to build technology that could find answers from unstructured data more effectively than standard search technology. "I joined right after the show and was able to contribute a lot to the machine-learning part of the project," he says.

Baughman joined the sports entertainment events group at IBM in 2013. With the pandemic, his team has been challenged in new ways to generate interest and excitement for sporting and entertainment events. For the first-ever virtual Grammys in March 2021, they created a series of structured debates, with Grammy Debates with IBM Watson. Baughman worked with the IBM Research Lab in Haifa, Israel, to create a music business application for Project Debater. Throughout Grammy night, thousands of fans used this platform to express their opinions on a variety of debatable statements, such as "Billie Eilish is the biggest style icon in music."

Baughman holds 241 U.S. patents and is ranked as the 226th most prolific living and deceased inventor in the world. Looking to the future, he says: "From an AI-based experience perspective, I'm always interested in how users can interface and use computing in new ways. I hope that we'll be able to use some of my inventions to accelerate a sustainable method of living."

— WH

Cleaning Up Transportation

AS CO-FOUNDER AND CTO OF CLEARFLAME ENGINE TECHNOLOGIES, JULIE BLUMREITER '08 IS TAKING the dirty out of the diesel engine and setting a new standard for sustainability in the transportation sector.

Ideal for heavy-duty industries like hauling, construction, and agriculture, diesel-fueled vehicles are critical to the global economy; more than 99% of all semitrucks are powered by diesel engines. The trade-off is that diesel fuel is a major source of harmful pollutants like nitrogen oxides, particulate matter, and carbon dioxide.

Blumreiter's team has reengineered the standard diesel engine to run on decarbonized and clean-burning alternative fuels like ethanol. Blumreiter says that a key feature of the technology is that it's suited to retrofitting; with just a little modification, manufacturers can easily integrate the ClearFlame solution into their existing production process.

The result is the same high-performance diesel engine, but with near-zero emissions. "We're taking an unconventional approach to cleaning up transportation," says Blumreiter. "Our low-cost technology can help policymakers and regulators meet even the most aggressive emissions reduction goals this next decade and beyond."

Blumreiter, a mechanical engineer, leads ClearFlame's prototyping and testing efforts. She began developing the low-carbon engine technology as a PhD student in Stanford University's Advanced Energy Systems Lab. In 2016, she and her labmate B.J. Johnson founded ClearFlame.

Since then, the startup has secured more than $3 million in grant funding and $5 million in venture funding to push the technology toward commercialization. The company was part of the first cohort of the elite Chain Reaction Innovations program at Argonne National Laboratory. And this year, it began integrating the technology into its first semitruck prototype, which will soon begin on-road testing.

A self-proclaimed "tender-hearted engineer," Blumreiter says she's found a way to merge her research prowess with her desire to make life — and the planet — better.

"I'd go back and forth between deeply technical engineering research and volunteer work where I could help someone in need. I've brought my interests together as an engineer focused on energy solutions who can work in diverse geographies and economies," she says. "My motivation is to expand energy access across the globe while simultaneously lowering emissions that threaten our environment."

— CATHERINE GRAHAM

Julie Blumreiter

Personalized Treatment for PTSD

DURING A TRAUMA, OUR BODIES GO INTO A STATE OF SYMPATHETIC RESPONSE, commonly known as fight-or-flight mode. For some people with post-traumatic stress disorder, this state of hypervigilance becomes the status quo, and symptoms such as irritability and an overactive startle response feel impossible to shake.

Blythe Karow '02, co-founder and CEO of Evren Technologies, has developed a medical device to treat PTSD. The Phoenix is an earbud, worn for about an hour a day, that delivers an electrical stimulation to the vagus nerve, which carries signals to the brain. The stimulation, which Karow says feels like "a light tingle" and adjusts based on the user's stress level, boosts the parasympathetic response to put the user in a more relaxed state.

"We're providing personalized medicine within the Phoenix earbud," says Karow.

In a 10-person proof-of-concept study, Karow says 90% responded to the treatment, and those users saw a 21-point average reduction in the severity of their PTSD symptoms. In July, the Phoenix became part of the U.S. Food and Drug Administration's Breakthrough Devices Program, a designation for devices that provide better treatments for serious conditions and that is meant to speed up its development and review process. The device could be available to the public as early as 2023, Karow says, and reimbursement could be accelerated, depending on forthcoming rulings by the Centers for Medicare and Medicaid Services.

The granddaughter of a research pharmacist, Karow realized at Johns Hopkins that she wasn't meant for the laboratory. In her third year, she landed a pivotal internship at Medtronic, a global medical technology firm, which sent her down the path of medical device development.

Karow says she thrives on understanding and addressing her customers' pain points. "A lot of people think, 'If you build it, they will come,'" she says. "But I'm very focused on human-centered design."

After earning her master's degree in business administration from the University of Virginia and working with and consulting for startups and major medical device companies, Karow moved home to Gainesville, Florida, in 2017. She connected with her co-founder, serial entrepreneur Weaver Gaines, and together they met University of Florida scientists who were researching the use of vagal nerve stimulation for PTSD.

"I was like, 'Hold up, I know PTSD,'" Karow says. "I come from a very long tradition of military service. I know there's a great need." Soon after, those scientists joined Karow and Gaines to become Evren's co-founders.

— CHRISTINA HERNANDEZ SHERWOOD

Blythe Karow

Feeling Strong

"Feeling strong just helps me feel like myself. I love feeling connected to my body, and working out helps me keep that connection."

— AMY WELDON

AS A PROFESSIONAL COMMUNICATOR, AMY WELDON UNDERSTANDS THE PROVERBIAL POWER OF THE PEN — how choosing just the right word or phrase can not only educate and inform but also change minds and hearts.

But Weldon is equally conversant with a different kind of power — one that comes from putting her body to the test lifting weights as heavy as 415 pounds. A communications specialist for the Department of Materials Science and Engineering and the Institute for NanoBioTechnology, she is a strongwoman and an avid participant in that sport's organized competitions.

"Feeling strong just helps me feel like myself. I love feeling connected to my body, and working out helps me keep that connection," says Weldon, who spends two to four hours doing deadlifts, push presses, and squats four days a week at local gyms, racking up personal records and training for her next competition.

Weldon began incorporating weights into her workouts about six years ago and quickly became an enthusiast. She is now coached virtually by a professional who lives in Germany.

"I started with a powerlifting for beginner's program I found on the internet," she says. "I transitioned to strongman training in January of 2020 after being introduced to the sport by my powerlifting coach and making a lot of strong new friends while attending the Official Strongman Games [in North Carolina] in 2017."

Since then, Weldon has taken part in competitions in Baltimore; Johnstown, Pennsylvania; Scotland (where she earned her master's degree in science communications); and Norway. She has garnered more than 7,500 followers on her Instagram profile, @charmcitychick, focusing largely on her strongwoman training, empowering women, and mental health.

In addition to relishing the sport's physical challenges, Weldon cherishes both the community she has found and a new appreciation for her body.

"As women, we are often pitted against each other by society, so finding this group of strong women who outwardly and fiercely supported me and each other taught me to think better of my fellow women and myself," she says.

"Strength sports are all about what your body can *do*. Lifting has changed my focus completely from how I look to what I can accomplish in the gym, and made me feel comfortable and proud of my own body."

— LISA DENIKE ERCOLANO

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Life Lessons from the Ring

Before spending eight weeks last summer working with youth at an East Baltimore boxing gym, Roy Sun had never slipped on a pair of boxing gloves.

"I'd done work at youth camps before, but a boxing gym was the last place I imagined myself," says the third-year chemical and biomolecular engineering major from Pittsburgh.

Sun interned at Corner Team Inc., which uses Olympic-style boxing and other programs to teach youth healthy lifestyles and leadership skills. The gym also provides programs for senior citizens and those with disabilities.

Sun's work was part of the university's Community Impact Internships Program, which provides undergrads with paid summer internships with nonprofit organizations and government agencies in Baltimore, giving participants real-life experience and providing organizations with much-needed help. His duties ranged from leading youth ages 14 to 17 in meditation and yoga, to supervising STEM lessons, to helping the students master the art of blocking jabs and hooks during boxing drills.

"Boxing is a great way to teach discipline, leadership, and self-esteem," says Sun. He also came away with a few lessons of his own: "The most valuable part of the summer," he says, "was having the opportunity to get to know the participants and hear their stories about growing up in Baltimore."

— LDE