THE JOHNS HOPKINS WHITING SCHOOL OF ENGINEERING MAGAZINE

JHU ENGINEERING

SPRING 2023

No Language Left Behind

Our experts are leveraging artificial intelligence to achieve digital equity.

Solution Builders

Experts in the Machine Shop bring ideas to life.

Civilian at Space Force

How one alum is leading efforts to make Earth a better place.

Bugging Out!

Creepy-crawlies play a crucial role in engineering's research ecosystem.

FROM THE DEAN

Dear WSE community,

THERE IS CURRENTLY CONSIDERABLE PUBLIC DISCOURSE ABOUT CHATGPT, AN AI TOOL THAT CAN GENERATE coherent, seemingly researched narrative responses when given a basic prompt. Other AI tools such as Midjourney can generate images—art, if you will. While these technologies are impressive, it's also unsettling to realize how difficult it is to discern content generated by a computer from what previously required the human creative process.

There are legitimate concerns in academia about ChatGPT providing misinformation and students passing off AI-generated content as their own. But before we decide these tools threaten education and more, let's pause to consider some of the amazing things these technologies can do and how we can harness them to improve teaching and learning.

My high school class was one of the first to skip the textbook chapter on how to use a slide rule as a result of the introduction of the four-function calculator. Concerns arose about whether calculators would replace students' basic arithmetic skills and what it would mean if students were allowed to use them on tests. Similar fears are being expressed about ChatGPT.

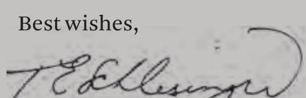
Instead, calculators profoundly minimized rote learning, and as teachers embraced the technology, they were able to expand curricula and empower students to use higher-level analytical skills. Indeed, while the introduction of AI tools could result in some negative educational consequences, it is our job as educators to help students bridge the gap between using their own intelligence and responsibly enhancing their intellectual skills by utilizing AI.

ChatGPT can enable new opportunities across all disciplines. What gives AI its power are human-created algorithms leveraging data and data science. Partnering human intelligence and AI opens a world of possibilities. AI systems will themselves collect and generate new data on a scale never before conceived, enabling discovery at a pace we had not previously imagined.

In this issue, we explore how AI and data help fill in the blanks and map linguistics as we seek to address the issue of under-resourced languages (p. 14), how fruit flies can help us understand the human mind (p. 20), and how in something as familiar as a machine shop (p. 26), experts use sophisticated tools to solve problems—as well as to create even more sophisticated tools.

I hope you will join me in discovering how AI and data science can be used to help us expand knowledge, enhance our students' education, and improve the world.

Best wishes,



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NO LANGUAGE LEFT BEHIND (P. 14)

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TRACI DABERKO

BUGGING OUT! (P. 20)

Daberko is a Seattle-based illustrator and graphic designer who has worked with a diverse range of clients across the globe, including Starbucks, Nordstrom, *The Wall Street Journal, National Geographic Books,* and *Martha Steward Living.*

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Cover illustration by Traci Daberko.

NASA

Safe in Space

JOHNS HOPKINS ENGINEERS ARE PARTNERING WITH THOSE AT CARNEGIE MELLON UNIVERSITY to ensure that additively manufactured metal parts used by NASA in everything from rocket engines to human outposts on other planets are durable and capable of withstanding the stress of the space agency's most ambitious missions.

The JHU-CMU team is spearheading one of NASA's two new Space Technology Research Institutes, which bring together university-led teams to develop technology. While the JHU-CMU institute will work to enable rapid certification of metal parts created using advanced manufacturing techniques, another at the University of Texas at Austin will focus on quantum sensing technology. Each will receive up to $15 million over five years.

"It's not overstating to say that the results of our Space Technology Research Institute will mark a paradigm shift in the way these materials are produced, qualified, and certified as being equal to the jobs they will be asked to do on critical space missions," says Somnath Ghosh, the Michael G. Callas Professor in the Department of Civil and Systems Engineering, who is co-principal investigator of the institute and will co-direct STRI with Tony Rollett at CMU.

Additively manufactured metal parts are made from powdered metals that are melted and shaped for use as components. It is difficult to accurately predict how these materials will behave in real environments and impractical for NASA to test every part in all possible scenarios.

The STRI group will perform testing using "digital twins": computer models that will allow the team to understand the parts' capabilities and limitations. Such models not only enable optimization of process-structure-property relationships that are key for certifying the parts for real-world use, but also save time and money.

The team will also use the same approach, which employs physics, mechanics, and machine learning, for evaluating and modeling new materials.

Ghosh predicts that the result will be a game changer not only for NASA, but also for aircraft companies.

— LISA ERCOLANO

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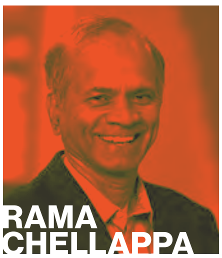
AWARDS AND HONORS

ARTIFICIAL INTELLIGENCE EXPERT



Johns Hopkins Bloomberg Distinguished Professor and artificial intelligence expert **Rama Chellappa** has achieved one of the engineering field's highest distinctions: election to the National Academy of Engineering.

Academy membership recognizes individuals who have made outstanding contributions to engineering research, practice, or education. Members advise the U.S. government on matters pertaining to engineering and technology.

Chellappa, who holds appointments in electrical and computer engineering and biomedical engineering and is chief scientist at JHU's Institute for Assured Autonomy, was honored for "contributions to digital image analysis, automatic face recognition, and applications."

Chellappa studies computer vision, artificial intelligence, and machine learning in areas ranging from biometrics, smart cars, and forensics to 2D- and 3D-modeling of faces, objects, and terrain. His book, *Can We Trust AI?* (Johns Hopkins University Press, 2022) explores topics such as transparency of AI in regard to the so-called black box problem, the reliability of self-driving cars, and more.

INTERNET PIONEER

KRISHAN SABNANI, Homewood Distinguished Professor in the Department of Computer Science, has been named a Fellow of the National Academy of Inventors, a distinction that recognizes and honors those who have created or facilitated outstanding inventions that have had an impact on society.

A member of the National Academy of Engineering, Sabnani is a networking researcher who has made many seminal contributions to internet infrastructure design, protocol design, and wireless networks. His groundbreaking work helped shape both the internet and cellular networks, substantially reducing network infrastructure costs.

His breakthrough discovery in internet redesign was to separate control functions and complex software from the forwarding portions on internet routers. He was also the first to develop a systematic approach to conformance testing, allowing communications systems to work together and reducing test time from weeks to a few hours.

EARLY PROMISE

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

YAYUAN LIU, Chemical and Biomolecular Engineering, received funding for her project: "Electrochemically Mediated Carbon Dioxide Separation via Non-Aqueous Proton-coupled Electron Transfer."

JEREMIAS SULAM, Biomedical Engineering, received funding for his project: "Interpretable and Robust Machine Learning Models: Analysis and Algorithms."

High-Value Visits

UNDERGRADUATES FROM AROUND THE GLOBE VISITED THE WHITING SCHOOL OF ENGINEERING IN MID-MARCH TO TAKE PART IN THE inaugural 2023 Hopkins Engineering Exploratory Program (HEEP), a weeklong initiative aimed at providing exceptionally accomplished international students with the chance to experience Johns Hopkins and learn about the university's master's degree programs, renowned faculty, and cutting-edge research, and the abundant cultural opportunities Johns Hopkins students enjoy in the Baltimore-Washington, D.C. region.

"Our goal was to allow students to immerse themselves in all that the Whiting School has to offer graduate students as well as provide them with guidance on how to apply and facilitate their interactions with current students and faculty," says Sri Sarma, vice dean for graduate education and lifelong learning at the Whiting School and associate professor of biomedical engineering.

Among the program's highlights was the faculty lecture series, covering research topics ranging from artificial intelligence and engineering in medicine and health care to engineering management and JHU's COVID-19 dashboard.

Domestic students already admitted to master's degree programs in mechanical engineering also attended the program. — LE

Elevating Equity in Faculty Advancement

SUPPORTED BY A $3 MILLION NATIONAL SCIENCE FOUNDATION GRANT, EXPERTS AT JOHNS HOPKINS, NEW YORK, AND CARNEGIE MELLON UNIVERSITIES ARE DEVELOPING A MODEL FOR institutional change that not only supports equitable advancement and support of faculty from groups underrepresented in engineering, but that other peer institutions also can customize and use.

Project ELEVATE (Equity-focused Launch to Empower and Value AGEP Faculty to Thrive in Engineering) is part of the NSF's Alliances for Graduate Education and the Professoriate program.

"We are creating a career-pathway model that will help all three institutions, as well as countless more, ensure we have inclusive cultures that enable all members to reach their full potential," says Darlene Saporu, assistant dean for diversity and inclusion at the Whiting School, and co-principal investigator on the grant.

Andrew Douglas, professor emeritus in the Whiting School's Department of Mechanical Engineering and former vice provost for faculty affairs, is the project's principal investigator, with Saporu and Ed Schlesinger, Benjamin T. Rome Dean of the Whiting School, serving as co-PIs.

First steps include a self-study and external evaluation to assess each institution's policies and practices. "We are looking at the institutional systems that faculty from underrepresented groups must navigate, from hiring and onboarding to promotion and tenure, and we're analyzing which policies are not equitable or transparent," Saporu says.

Central to the project will be robust mentorship programs pairing tenure-stream faculty members with trained faculty members—all full professors—at partner institutions. "Mentors have an important role in helping a person understand unwritten rules and norms," says Saporu. "We think it will be easier for early career faculty to talk openly about challenges and to ask questions if their mentors are not at their own institutions," says Saporu.

Project ELEVATE faculty from all three universities will gather in the Baltimore area early this summer for a retreat and social justice training offered by Baltimore nonprofit Thread, founded by Sarah Hemminger '02, PhD '10. "The goal of the retreat is to harness the power of relationships, learn active listening, reflect on the values of privilege, overcome barriers, and interrogate power," Saporu says. "All of these are important discussions, but we are just getting started."

— LE

TACKLING THE 'IMPOSSIBLE'

LAST YEAR, THE WHITING SCHOOL AND THE JOHNS HOPKINS APPLIED PHYSICS LABORATORY partnered to create SURPASS, an initiative aimed at developing groundbreaking solutions to some of the world's most pressing problems. In this first year, the program received 47 initial whitepaper submissions, seven of which were chosen as finalists. Of those, four were selected to receive funding.

The four winning proposals are:

- BEAST: Between Earth and Space, the Next Strategic Flight Regime, with principal investigators Kevin Hemker (Whiting School) and Melissa Terlaje (APL)
- CEREBRO: Enabling the Next Step of Human Evolution, with principal investigators Amy Foster (Whiting School) and Nicholas G. Pavlopoulos (APL)
- Organoid Intelligence: Synthetic Biological AI, with principal investigators Thomas Hartung (Whiting School/Bloomberg School of Public Health) and Erik C. Johnson (APL)
- Photoacoustic Retinal Prosthesis, with principal investigators Emad Boctor (Whiting School) and Seth Billings (APL)

SURPASS program organizers say these proposals have the potential to lead to larger translational efforts with external funding upwards of $100 million. The Whiting School is providing funding of approximately $3.75 million to be shared across the four selected projects over an 18-month period.

— LINDA MCLEAN AND JUSTYNA SUROWIEC

OPPOSITE PAGE PORTRAIT OF JILL MIDDENDORFF: WILL KIRK/HOMEWOODPHOTO.JHU.EDU.

The Mechanics of Back Pain

Jill Middendorf

IT'S A FAMILIAR STORY: YOU FEEL A TWINGE IN YOUR BACK AND NEXT THING YOU KNOW, you can't get out of bed. From back pain to achy joints, musculoskeletal pain can be life-changing and debilitating. But does it have to be?

That's the question for Jill Middendorf, an assistant professor of mechanical engineering who studies the mechanical factors that cause our cartilage, ligaments, and joints to break down.

"Our goal is to understand the degeneration process of musculoskeletal tissues, including cartilage, ligaments, and intervertebral discs, using advanced mechanics techniques. If we understand why this process is happening, we hope to translate our findings into new methods to repair damaged tissues and prevent more pain," says Middendorf.

In a study published by the *Journal of Biomechanical Engineering*, Middendorf and collaborators sought to understand how the soft tissues of the spine change as spinal discs break down, or degenerate, over time. Specifically, they looked at the facet capsular ligament, a soft tissue that holds the two sides of the facet joint together and is thought to be a common cause of lower back pain. Previous studies suggest this could be related to mechanical changes that occur in this ligament during spinal degeneration, though it's not clear exactly why.

To find out, the team extracted facet capsular ligaments from cadaver spines and ran experiments to measure their mechanical properties, like stress and strain, under different loading conditions. By comparing MRI scans of the spine and their experimental results, the team discovered that the tissues in the ligament became stiffer as the spine degenerated.

The researchers think this increased stiffness causes altered loading in surrounding tissues, potentially explaining facet joint pain.

"We show a correlation between the mechanics of the ligament and spine degeneration, which brings us even closer to being able to determine if this ligament is causing pain or if it's some other part of the spine," says Middendorf.

The researchers plan to work next on furthering our understanding of spinal degeneration and creating engineered musculoskeletal tissue that could be implanted to replace damaged or diseased tissue.

However, when it comes to pain, answers aren't always easy to find.

"One of the challenges associated with diagnosing and treating spine pain is determining the source of the pain. But we can understand more about the causes and mechanisms of tissue damage, and that means we will someday be able to reverse engineer a solution," says Middendorf.

— CATHERINE GRAHAM

Ben Hobbs

Beating the Heat

HEAT WAVES ARE DEADLY AND INCREASINGLY FREQUENT. THEY HIT urban areas harder than suburban or rural areas because cities have more heat-absorbing pavement, more buildings, and more people. But what if cities had a tool that could help them develop strategies to protect their citizens from deadly heat?

The City-Heat Equity Adaptation Tool (City-HEAT) is a decision tool that offers cities individualized, optimized strategies for reducing the urban heat island effect and its health impacts through modifications to the built and natural environments and reduction of people's heat exposure.

It offers flexible decision-making that lets the user set priorities while also taking into consideration future uncertainties, says Ben Hobbs, the Theodore M. and Kay W. Schad Professor in Environmental Management in Environmental Health and Engineering, and one of the tool's creators, along with PhD student and lead author Rui Shi. The work was published in *Science Direct*.

"[City planners] want to determine the best alternatives given conflicting objectives like equity, cost, and other considerations, combined with uncertainty around how climate change will advance and present itself, how long and how well certain tactics will work, and how urgently they need to address the problem," says Hobbs.

For example, it can take a decade before tree planting makes a difference, whereas cooling centers, which offer air-conditioning and water to citizens in need, offer immediate relief from the heat. That distinction can be crucial for vulnerable populations, Hobbs notes, since heat and heat-related injury and deaths tend to be concentrated in poor and minority neighborhoods that have been underserved over decades, setting them up for greater consequences from heat events. They have less green space, more housing stock that is rundown, poorly ventilated, and lacks air conditioning, and populations with bigger health challenges and less access to health care, he says.

The tool is currently "research grade," which means that developers who are familiar with the tool can use it, but it needs a practical user interface that could be used by a layperson.

In simple terms, users input their objectives (reduce mortality, improve equity across neighborhoods, increase green space, minimize cost, etc.) as well as localized data on climate, demographics, geography, and temperature trends. The tool then suggests an optimal set of strategies based on the objectives and the data.

Baltimore will likely be the first city to benefit from the tool, which is being enhanced as part of Johns Hopkins 21st Century Cities Initiatives' Baltimore Social-Environmental Collaborative, whose goal is to seek equitable climate solutions. That work is being conducted in cooperation with the Baltimore Office of Sustainability and community members.

— DANIELLE UNDERFERTH

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Mathias Unberath

"We demonstrated that models trained using only simulated X-rays could be applied to real X-rays from the clinics, without any loss of performance."

— MATHIAS UNBERATH

Simulating Data for AI Surgical Solutions

WHILE ARTIFICIAL INTELLIGENCE CONTINUES TO TRANSFORM HEALTH CARE, THE TECH HAS AN Achilles' heel: Training AI systems to perform tasks requires annotated data that engineers sometimes just don't have or cannot get.

In a perfect world, researchers would be able to digitally generate the exact data they need when they need it. In reality, however, even digitally generating this data is tricky because real-world data, especially in medicine, is complex and multifaceted. But solutions are in the pipeline. Researchers in the Laboratory for Computational Sensing and Robotics have created software that realistically simulates the data necessary for developing AI algorithms that perform important tasks in surgery, such as X-ray image analysis.

The researchers found that algorithms built with the new system, called SyntheX, performed as well as or even better than those built from real data in multiple applications, including giving a robot the ability to detect surgical instruments during procedures. The results appeared in *Nature Machine Intelligence*.

"We show that generating realistic synthetic data is a viable resource for developing AI models and much more feasible than collecting real clinical data, which can be incredibly hard to come by or, in some cases, simply doesn't exist," says senior author Mathias Unberath, an assistant professor of computer science.

Take X-ray guided surgery, for instance. Say you want to develop a new surgical robot and the related algorithms that will ensure that it puts instruments in the correct places during an X-ray guided procedure. But the training dataset needed—in this case, highly specific X-ray images—doesn't exist.

The answer? Generate the data needed through simulation, say the researchers. To test this approach, the team performed a first-of-its-kind study in which the team members created the same X-ray image dataset both in reality and in their simulation platform.

First, they took a series of real X-rays and CT scans, acquired from cadavers. Next, they generated "synthetic" X-ray images that precisely recreated the real-world experiment. Both datasets were then used to develop and train new AI algorithms capable of making clinically meaningful predictions on real X-ray images. The algorithm trained on the simulated data performed as well as that trained on real data.

"We demonstrated that models trained using only simulated X-rays could be applied to real X-rays from the clinics, without any loss of performance," Unberath says.

The system appears to be one of the first to demonstrate that realistic simulation is both convenient and valuable for developing X-ray image analysis models, which paves the way for all sorts of novel algorithms.

—CG

The Physics Behind Friction

WITHOUT THE FORCE CALLED FRICTION, CARS WOULD SKID OFF THE ROADWAY AND OBJECTS would tumble off tables and onto the floor. Even so, how friction works at a molecular scale remains poorly understood.

Now, using complex modeling and computer simulations, a team that included Johns Hopkins mechanical engineer Jaafar El-Awady has shed new light on a particular feature of friction known as "aging." The team's findings, which appeared in *ACS Nano*, could inform the design of improved prosthetic devices and artificial joints, the researchers say.

Aging occurs "when one solid rests on another for a long time without sliding, and the force needed to slide them apart increases. We wanted to find out why," says study leader Lucas Frérot, formerly a postdoctoral researcher at the Whiting School and now at Germany's Albert-Ludwigs-Universität's Institut for Mikrosystemtechnik.

Previous experiments by researchers at France's Laboratoire de Tribologie et Dynamique des Systèmes at École Centrale de Lyon gave a very detailed picture of the friction response of surfaces coated with fatty acids, an environmentally friendly family of lubricants. But those alone couldn't explain the phenomenon behind aging. Using measurements of surface roughness and the properties of the single-molecule-thick layer of fatty acid molecules, the Johns Hopkins team used molecular simulation to reproduce the aging process.

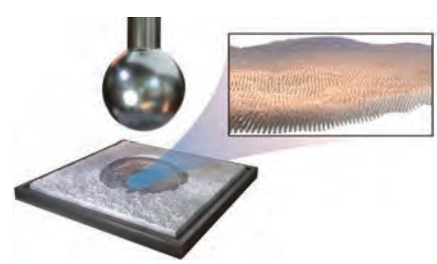
"That allowed us to try things impossible in experiments, such as what would happen if the surfaces in contact were mathematically flat," says El-Awady, program chair of mechanical engineering in the Whiting School's Engineering for Professionals programs.

They found that the main cause of aging was surface roughness, concluding that even a small amount of roughness is enough to prevent the molecules from making contact over the whole surface, leaving the molecules on the edges of contact spots free to move. Over time, more molecules come in contact, resulting in aging.

Although the mechanism discovered is not the only one that can explain why frictional systems age, the team believes it can be applied to a wide range of systems where chain-like molecules, such as the fatty acids they studied, form a protective layer on a surface.

"This is the case in biological systems like joints, and if we understand those systems better, we can design better and more durable prostheses," Frérot says. "In a more general sense, understanding the physics behind friction is important in the design of sustainable systems. Some studies estimate that about 23% of the world's energy consumption is lost to friction."

— LE



Deposited on rough surfaces, fatty acid layers form contact junctions that explain frictional aging, as was highlighted by cutting-edge research combining friction experiments, molecular simulations, and a theoretical model.

THIS PAGE: ILLUSTRATION COURTESY OF THE RESEARCH TEAM.

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3 Questions

Tak Igusa on tapping technology to provide healthy food options

Interview by Lisa Ercolano

East Baltimore corner mini-markets serve a vital function, providing residents with access to goods ranging from toiletries to convenience foods. Very few corner stores, however, offer fresh fruits, vegetables, and other healthy options because they are expensive and difficult for individual small business owners to procure.

Enter the Baltimore Urban Food Distribution app, a smartphone-based tool that connects local store owners to each other and to wholesalers who can sell them lettuce, apples, and other healthy foods at reasonable prices.

"Until now, store owners who wanted to offer customers fresh food had to get in a car and drive to a local supermarket and buy it there—an expensive way to do things that cancels out any profit they might make. The app promises to change that," says systems engineer Tak Igusa, who worked with project leader Joel Gittelsohn and a team at the Bloomberg School of Public Health on the app's creation.

1 What's innovative here?

This is either the first—or one of the first—interventions that engages with a local food system at multiple levels. Though the app links store owners to harness their collective buying power, the ultimate goal is to improve access to healthy food—and positively impact the health of residents—in low-income communities.

2 How was engineering involved?

Food systems seem simple on the surface, but they are actually complex and comprise many stakeholders, from food distributors to corner-store owners to consumers. In engineering, we talk about multiobjective optimization, which means finding the best solution to achieve multiple goals. In this case, we had to consider the interests of the customers, but also that of store owners, and residents.

3 Is it working?

We're piloting its use now with a small group of store owners, with one doing the driving to get the food. Results are promising. In the future, our goal is to have autonomous vehicles do the food delivery—but one step at a time!

Building Antibody Libraries

WHEN THE COVID-19 PANDEMIC SHUTTERED LOCAL PUBLIC LIBRARIES IN EARLY 2020, ANOTHER KIND of library not only flourished but also proved crucial in the fight against the novel coronavirus: the antibody library.

An invaluable tool in the discovery and development of new therapies, these libraries are collections of genetically engineered antibodies used in research and industry to discover and develop therapies for viruses, cancer, and other diseases. For instance, antibody libraries provided researchers with a blueprint for synthesizing the molecules now used in COVID-19 vaccines.

While antibody libraries have great potential to help in the discovery of new treatments, their usefulness is limited by the time and expense involved in their creation and the fact that significant numbers of sequences have poor chemical properties that need to be reengineered before therapeutic use.

A Johns Hopkins team has a new approach that could expedite the antibody creation process and accelerate the discovery of therapeutic antibody candidates, minimizing risks to proper immune response. Their results appeared on bioRxiv.

"[Antibody] libraries are usually generated by engineers randomly mutating sequences. The result is that not every antibody generated is going to work or be well behaved in the body. Our approach is different: We used a deep-learning, artificial intelligence model to create high-quality libraries on demand," said team leader Jeffrey Gray, professor of chemical and biomolecular engineering and an associate in the Institute for NanoBioTechnology.

The researchers' "Immunoglobulin Language Model (IgLM)" was trained on a set of half a billion real human antibody sequences, allowing them to accurately predict and fill in gaps. It can take an existing antibody sequence and diversify a particular region, potentially allowing the creation of antibodies that resemble those produced by the immune system, subverting existing quality control issues.

And because the model was trained on a species other than humans, it can be used to generate antibodies for mice, primates, and more, in addition to humans. SARS-CoV-2, for example, manifests differently in humans and apes, and the antibody library can quickly be shifted between the two.

Though the researchers' efforts so far are limited to creating antibody libraries on the computer, they are seeking a partner to move into experimental testing, Gray says.

"We believe IgLM has real promise, but we need a collaborator to experimentally screen our libraries to find antibodies against specific ailments," he says. "In principle, we can do this, but we need further experiments to prove it."

— JONATHAN DEUTSCHMAN

TECH TOOLS

'The Most Expensive Saw on the Planet'

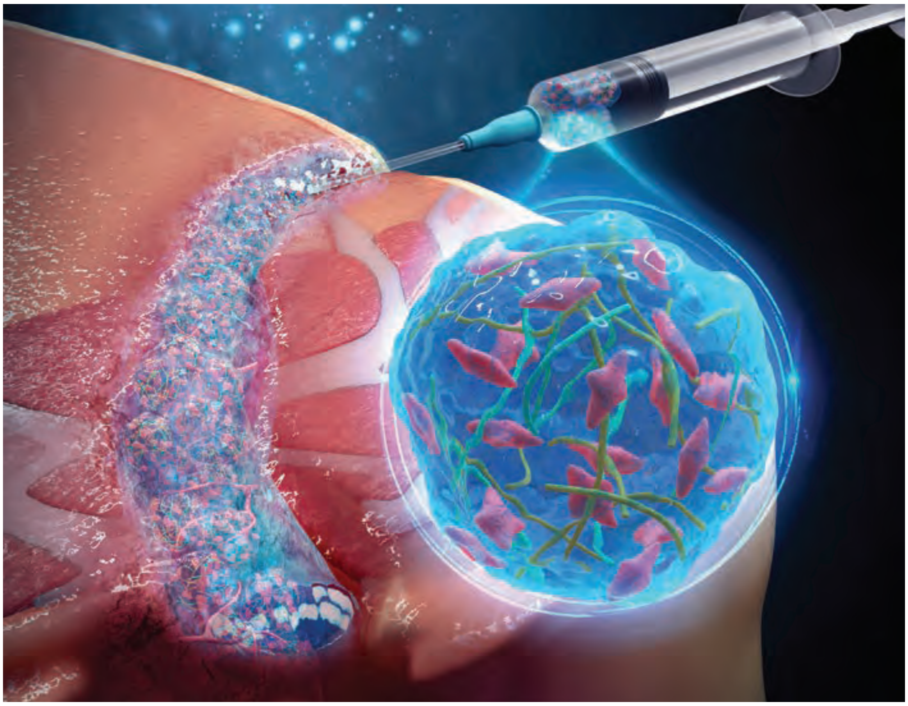
Nestled in the newly renovated Materials Characterization and Processing facility in the Johns Hopkins Stieff Silver Building is "the most expensive saw on the planet," says the facility's director and professor of materials science and engineering, Mitra Taheri. "It can shoot gallium ions to slice and dice and cut materials down to the nanometer," the metric unit of length equal to one billionth of a meter.

Used to make something on the nano scale, like a computer chip or microelectromechanical system, a focused ion beam scanning electron microscope (or FIB-SEM) can cut a human hair—approximately 50 micrometers wide—lengthwise into 10 to 20 slices. It can also drill a hole that is only a few nanometers in diameter.

Researchers at the MCP facility use the Helios G4 UC DualBeam FIB-SEM, made by Thermo Fisher Scientific, to fabricate nano devices and make thin slices of materials. They then take these slices and place them in the facility's transmission electron microscopes, which can resolve individual atoms.

"It takes a lot of training to make these slices," says Kenneth Livi, MCP's director of operations and associate research scientist in the Department of Materials Science and Engineering, "but the effort is worth it to discover the inner workings of things."

— MONICA LEIGH



"These results are very exciting for the future of bio-stimulation tissue repair for chronic injuries."

—HAI-QUAN MAO

Toward a New Treatment for Crohn's

CROHN'S DISEASE IS AN INFLAMMATORY BOWEL DISEASE that affects an estimated 780,000 Americans, with even higher rates reported in Canada and Europe. Among its many complications are perianal fistulas: tunnels that develop between the inside of the anus and the skin around it. Often resistant to treatment, severe fistulas can lead to incontinence, infertility, and decreased quality of life.

Johns Hopkins researchers have developed an injectable, biodegradable, mechanically fragmented nanofiber-hydrogel composite (mfNHC) loaded with stem cells that could deliver new treatment for fistulas. The composite results in faster and a higher degree of healing, reducing the volume of fistulas sixfold in comparison to the surgical treatment. The team's results appear in *Science Advances*.

"These results are very exciting for the future of bio-stimulation tissue repair for chronic injuries even beyond PAF," says Hai-Quan Mao, professor in the Department of Materials Science and Engineering and one of the project's core researchers. Mao is also director of the Johns Hopkins Institute for NanoBioTechnology.

The mfNHC comprises a hydrogel of hyaluronic acid infused with electrospun nanofiber fragments, forming a fully integrated substance that breaks down in the human body slowly, according to Zhicheng Yao, a co-first author of this study and a PhD student in the Materials Science and Engineering program who is a mentee of Mao. The nanofibers give the substance enough stiffness so that the gel retains its shape, while still being porous enough to provide a scaffold for regenerative host cells, which migrate into the area and begin to rebuild the affected tissue. In the case of perianal fistulas, it is injected directly into the fissure to promote regeneration.

"Perianal fistulas in Crohn's patients are notoriously difficult to treat. Our results could represent a new treatment paradigm to improve the quality of life for patients with Crohn's disease," says Florin Selaru, associate professor of medicine and oncology in the Johns Hopkins School of Medicine's Division of Gastroenterology and Hepatology and director of the Meyerhoff Inflammatory Bowel Disease Center, and one of the project's senior authors.

Though still working to understand the bio-stimulation repair mechanism, the team plans to continue work on the composite, improving it "from a biomaterials perspective," says Mao. "We are exploring the idea of a foam version as well."

— JACK DARRELL

THIS PAGE: ILLUSTRATION CONTRIBUTED BY LING LI, ZHICHENG YAO, FLORIN, AND HAI-QUAN MAO.

“Honestly, with the data that I’ve seen on the EPA response site, the answer is no.”

2/16/23 NPR
Peter DeCarlo, Environmental Health and Engineering, on whether he thought residents of East Palestine, Ohio, were safe to return home after a Norfolk Southern freight train derailed, releasing toxic chemicals

“The brain is the physical object that makes us who we are. This is the landmark first reference that we can use to compare everything else.”

3/9/23 NPR MORNING EDITION
Joshua Vogelstein, Biomedical Engineering, on his team’s successful completion of the connectome of the brain of a larval fruit fly

“People would be shocked about how our trails of breadcrumbs from our mobile devices and other platforms can be used, especially by nation states, and in different ways that can be a threat to national security.”

2/2/2023 *TIME*
Anton Dahbura, Computer Science, co-director of the Institute for Assured Autonomy, on increasing concerns over use of Chinese-owned app, TikTok

“We’re more in the taking-the-cap-off-of-the-toothpaste phase. The toothpaste won’t be out of the tube probably for 10 years.”

2/2/23, *Politico*
Matthew Green, Computer Science, explaining that while advances in encryption and network design could bring further crypto-driven disruption, currently governments have shown they can and will find ways to crack down on networks used for criminal activities

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Inuktitut *for* “high fever”

NO LANGUAGE LEFT BEHIND!

Dlo Potab

Haitian Creole
for “potable water”

Four billion people around the world speak languages not served by Siri, Alexa, or chatbots—to the detriment of global public health, human rights, and national security. Here's how our experts are leveraging artificial intelligence to achieve digital equity for people the world over.

STORY BY Andrew Myers

In 2010, an earthquake devastated Haiti. Relief workers poured in from around the world. Makeshift cell towers were hastily raised to reestablish phone service. Desperate calls for help came from every direction, yet many went unheeded.

"Not from a lack of relief workers, but because no one spoke Haitian Creole," recalls Matthew Wiesner, a research scientist at the Center for Language and Speech Processing at Johns Hopkins Whiting School of Engineering.

Wiesner first learned of the Haitian example in 2016 while contributing to a U.S. Department of Defense initiative known as Low Resource Languages for Emergent Incidents (LoReLEI), whose aim was to help translate any language in as little as 24 hours after first encountering it.

The urgency of the Haitian example highlights the complex challenges experts at CLSP have grappled with for decades—bringing the power of natural language processing, like that behind Alexa, Siri, and ChatGPT, to the world's lesser-spoken languages. Depending on whom you ask, there are between 6,000 and 7,000 languages spoken on planet Earth today. As remarkable as that number is, experts estimate that half the world's people speak just 100 or so languages. That leaves a staggering four billion people speaking any one of the thousands in that long list of rare languages.

"That is a vast underserved population," says Sanjeev Khudanpur, an associate professor of electrical and computer engineering who leads the Center for Language and Speech Processing. "Many languages beyond the top 20 or 30 most-spoken languages don't work with Siri or Alexa. No one is developing chatbots in these languages."

A fair number of the 3,000 least-spoken languages in the world are so rare that they are in danger of becoming lost forever as the relative handful of speakers dwindles and no one steps in to keep the languages alive. Many Native American languages are endangered. Younger generations aren't learning them. These languages don't work on smartphones or proliferate on the internet.

Other languages present yet different challenges. Several thousand languages are rarely written and many lack a standardized writing system. Others lack digital alphabets to preserve them on computers where they can become valuable data sources. Such is the case in South Asia. The Devanagari alphabet exists on most operating systems, but is not as widespread as the Latin alphabet. And even then, less than half of South Asians speak languages written in Devanagari. Collectively, the population speaking languages lacking suitable digital alphabets could number a few billion people, Khudanpur says.

"Meanwhile voice recognition, translation, and natural language processing using AI are changing the world, but only for a select few languages," Khudanpur says. "If the language you speak is among the thousands of outliers, AI is not for you."

It is a matter of digital equity, Khudanpur stresses. Today's ubiquitous voice recognition applications, like Alexa and Siri, and artificially intelligent chatbots, like ChatGPT, are concentrated on a relative handful of the most-spoken languages—English especially. As AI becomes more powerful, the world's most-common languages will benefit. The rest will fall behind. Too many will die.

"If a Quechuan kid in Peru can't surf the web in Quechua, they'll use Spanish," says David Yarowsky, a professor of computer science and a computational linguist on the CLSP faculty. "This is a rapidly accelerating train."

The Center for Language and Speech Processing is one of the foremost academic research centers in the world studying computerized language processing, automatic speech transcription, and machine translation. The center conducts research in many relevant areas including acoustic processing, automatic speech recognition, cognitive modeling, computational linguistics, information extraction, machine translation, and text analysis, among others.

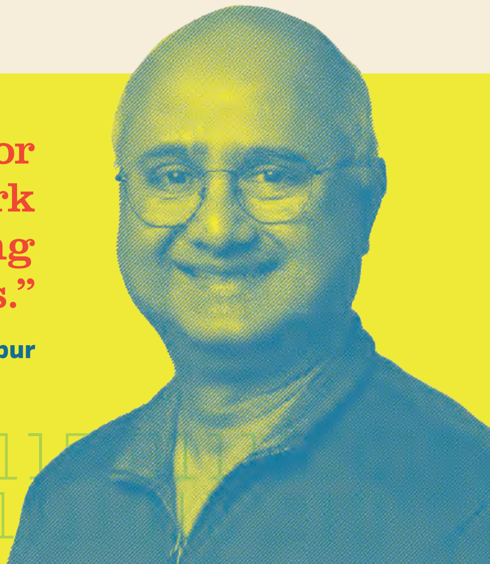
Khudanpur's handiwork is behind the voice recognition algorithm in Amazon's Echo—better known as Alexa. He imagines a world where computers and smartphones can instantaneously hear or read any language in the world, understand what's been said, and then translate those words into any other language on Earth instantaneously—an Amharic Alexa, a Chechen ChatGPT. But that dream is far, far off, he says.

Khudanpur and his colleagues at CLSP are applying their myriad skills to extend AI's reach to those underserved billions. The cause is one of cultural preservation, but increasingly, Khudanpur says, also a matter of national security, of global public health, and of human rights.

The National Science Foundation has taken particular interest in studying these so-called "underresourced languages" to preserve their cultural histories. Despite the concerted efforts of CLSP and others in academia and in industry to support them, many languages will fall silent, but the work could at the very least preserve them for posterity, the way archeologists, classicists, and anthropologists learn Latin, ancient Greek, hieroglyphs, and Old English to extract meaning from important cultures of the past.

"Many languages beyond the top 20 or 30 most-spoken languages don't work with Siri or Alexa. No one is developing chatbots in these languages."

— Sanjeev Khudanpur



"Loss of a language is loss of knowledge," Khudanpur says. "The Eskimo have some 50 words for snow. Perhaps one describes ice too thin to walk on."

The U.S. Department of Defense considers the study of rare and dying languages as a matter of national security. LoReLEI is but one example. Recall the urgent pleas for speakers of Urdu, Pashto, and tribal languages of Afghanistan and Pakistan in the early 2000's Afghanistan War. Understanding a rare language might distinguish a recipe for a babka from a recipe for a bomb or unlock a trove of information in a captured laptop. In a public health setting, knowing a rare language might help beat back the next pandemic or speed relief to victims of natural disasters like those victims of the Haitian earthquake whose calls for help went unmet.

"Johns Hopkins is one of the major forces in trying to provide the language technologies that will help make the thousands of languages remain viable," Yarowsky explains.

HOLY WORDS

Like many at CLSP, Yarowsky uses machine learning to study the structure and rules of language. Increasingly, the challenge comes down to data, or the lack of it—a deficit experts are referencing when they describe a language as "underresourced." There aren't vast stores of written text or hours of recorded speech to work from. Books and other materials that are a rich resource for the more widespread tongues are rarely translated into the lesser-spoken languages.

"There's a very long tail of languages that get left behind. And unfortunately, resources like GPT-3 and technologies like ChatGPT, Alexa, and Siri, even the internet itself, are making the digital divide worse," Yarowsky says.

GPT-3, the large language model behind ChatGPT's "intelligence," contains some 250 billion words of written text—almost all in English. That's more than 900,000 Bibles worth of written content, which just happens to be Yarowsky's go-to data source. The Bible has been translated into more than 1,500 languages by missionaries evangelizing in remote corners of the globe.

Yarowsky first got interested in language as a Rockefeller Fellow traveling the Himalayas soon after college. Roaming the villages, living among the Nepalis, learning their languages, he grew fascinated by the way different peoples express similar meaning. That passion became his life's work. He became a computational linguist and uses mathematics, algorithms, and artificial intelligence to map languages to one another. But mapping of words is just "scaffolding," as Yarowsky puts it. He is more deeply interested in semantics and the meaning of language.

To illustrate, Yarowsky turns to one of the Bible's shortest but best-known verses, "David killed Goliath." In his hands, those Hemingway-esque words reveal layers of meaning. Speaking the verse in Japanese, Yarowsky intones, "*Dabide ga goriate wo taoshita.*"

In a few words, we not only learn that David is "*Dabide*" in Japanese, but Goliath is "*Goriate*" and killed is "*taoshita*" by word-aligning the two languages as in Figure 1.

We also learn that in Japanese, the actor (the person who's doing the killing) is denoted with a "*ga*." "*Dabide ga*" is the killer. The subject of the action, the slain giant, is denoted with a "*wo*"—"*Goriate wo*." And that "*taoshita*" is a modification of the verb "*taosu*"—to kill—placing the action in the past tense, Yarowsky says.

Yarowsky is not doing such analyses for Japanese alone, nor for 10, 20, 100, or even 500 languages. "We're doing this for all 1,600 Bible translations," he says. "Essentially, every language that has a written form."

For Yarowsky, each of the Bible's many translations is a neatly mapped, word-for-word, sentence-for-sentence, verse-for-verse database upon which to train his algorithms. There are even 24 English variations of the Bible from which to draw meaning.

"It's like 1,600 Rosetta Stones," he says. "Each with hundreds of thousands of words of English and translated word for word in all those languages. In the linguistic context, it's actually not a lot of data, but it's enough to do a lot."

WELCOME TO THE MACHINE

The joke around CLSP is that faculty member Philipp Koehn wrote the book on machine translation—literally. In fact, he wrote two. The first was his foundational 2009 textbook *Statistical Machine Translation* and the second was 2020's *Neural Machine Translation*.

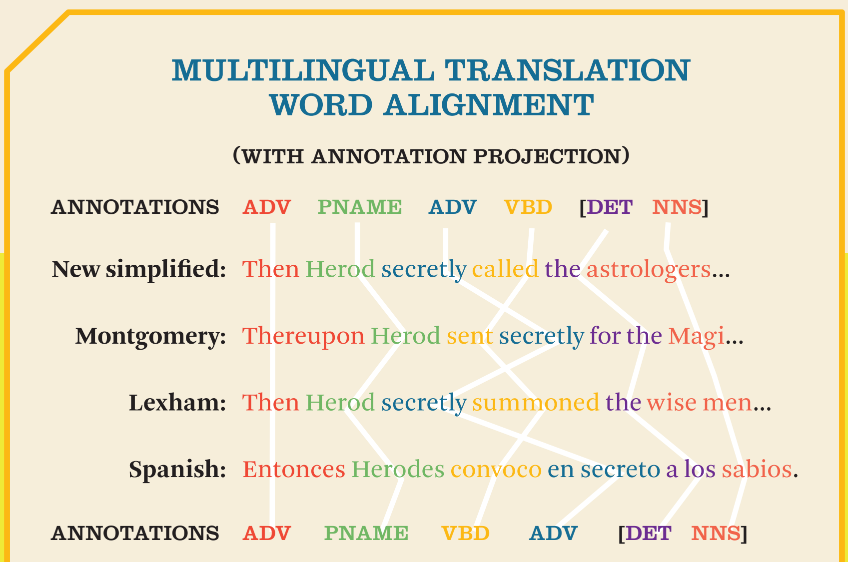


Figure 1. *A diagram of David Yarowsky's "scaffolding" mapping word pairs in three English language translations of the Bible to Spanish (bottom). Note the interchangeable use of astrologers, Magi, and wise men.*

Koehn pioneered a now widely adopted approach known as phrase-based translation that looks to translate small groups of words instead of individual words. He is also developer of the open source Moses statistical machine translation system. Statistical models use word and phrase probabilities to achieve translation. They were the dominant approach in machine translation until only the past few years, when neural network-based models ascended.

"The sea change from statistical to neural models happened almost overnight. Now, neural machine translation is used almost exclusively," says Koehn, a professor of computer science.

Some of Koehn's most recent work focuses on a many-to-many translation approach known as multilingual machine translation, which translates among three or more languages at the same time. One of his latest publications explores how lower-resourced languages might benefit. The grouping of similar but lesser-known languages capitalizes on linguistic overlaps and expands resources by sharing data from closely related languages. A machine translation system trained to negotiate between English and two related languages, say Assamese and Bengali, will also improve translation between Assamese and Bengali, Koehn's research shows.

For Koehn, the challenge is similarly one of finding good data in quantity. He says that it takes as many as 10 million words to build a good model—the more, the better. But the typical novel is just 200,000 words. In that regard, one of Koehn's go-to resources is recordings and written proceedings of European Parliament in which members speak and submit documents in any of the EU's 24 native tongues, which are then translated into English, the official language of the EU, and the others. The archives of the European Parliament consist of about 15 million words at present.

"I can imagine a day when we have automatic and instantaneous machine translations between almost any language," Koehn says.

SHARED VECTORS

The greatest challenge with underresourced languages is that often the word pairs between two languages have not been formally established, says Kelly Marchisio, a doctoral candidate in Koehn's group who is finding ways to translate unfamiliar languages sight unseen.

It's a strategy known as "bilingual lexicon induction," that uses AI and math to establish word pairs. Given a large amount of English text and a similarly large amount in any another language, Marchisio can calculate word pairs in languages she's never studied before.

"Imagine I talk to you for 10 hours in English about a random topic," Marchisio says, laying out a hypothetical. "Then I switch to German, which you don't speak, and talk for another 10 hours on a completely different topic. With just that amount of data, we can write programs that learn to translate between English and German without any interceding examples of translation."

In technical terms, Marchisio uses neural networks to calculate a series of mathematical parameters for each word—she calls groups of these parameters "vectors." Each word in each language is assigned its own vector. She then organizes the terms mathematically in multidimensional digital space, like big balloons of interconnected words where all words of similar meaning in both languages get grouped near one another: colors, animals, travel, weather, and so forth.

"If 'brown' and 'fox' are often used in conjunction in English, then they are likely to be similarly combined in German, as well," Marchisio says. With additional analysis, she can start to pair words from both languages.

On the precipice of earning her doctorate, Marchisio says she likes the democratizing nature of her work and helping to keep languages alive. Ideally, she hopes to bring the power of the internet and artificial intelligence to underserved peoples.

"Everybody deserves access to information," Marchisio says. "And they should be able do it in their native language."

> **"If you give me a recording of 30 minutes of someone speaking a language I've never heard before, in less that 24 hours we can create a transcription model that gets half the words right."**
>
> — MATTHEW WIESNER

TRANSLATING AT THE SPEED OF SOUND

Matthew Wiesner's Haitian relief example highlights the broad complexity of language processing. His realm is the spoken word, which introduces wholly new sets of challenges to CLSP. The frustrations experienced in Haiti birthed the Defense Advanced Research Projects Agency's LoReLEI, an effort to develop a language processing technology that works quickly, in a matter of hours, even with a language never heard before. Such capabilities hold great promise in low-resource language settings.

"Instead of working on Swahili, Zulu, Telugu, or Bengali, all of a sudden, we were working in Ilocano, spoken in the Philippines. Oromo, the second or third language of Ethiopia. Odia, the eighth or ninth language of India," Wiesner recalls. "Or, as in Haiti, Creole."

These emergency approaches don't need to be perfect, Wiesner says, they just need to work, and work quickly. He uses an approach known as cross-language modeling. In this strategy, AI helps to polish recorded speech, removing the unusable artifacts in the audio—background noise, the emotion of the speaker, and so forth.

The focus is strictly on the phonetics. Given a relatively few bits of recorded content, Wiesner builds a phonetic library of all the sounds in a language (the phonemes, in the linguist's terminology) and assigns them unique characters (the graphemes). This allows him to transcribe longer recorded pieces phonetically.

“For instance, in English we have two ‘P’ sounds,” Wiesner explains. “The P sound at the beginning of words, like ‘please’ where there’s a little H after the P,” he says, emphasizing the pronunciation, ‘puh-lease.’ “And then there’s the P sound after an S as in ‘spin.’ We need a way to write both.”

With these phonetic transcripts, Wiesner does not care about spelling or even where one word stops and another starts. He just wants accurate and consistent phonetic spellings. Then, as with printed text, those phonetic spellings serve as patterns to which neural networks can apply traditional language processing techniques.

Wiesner has found that these rapid cross-language strategies work best by pooling all graphemes of all languages in a single universal library—one collection of all the spoken sounds of all the world’s languages.

“If you give me a recording of 30 minutes of someone speaking a language I’ve never heard before, in less that 24 hours, we can create a transcription model that gets half the words right,” Wiesner says. “It’s not perfect, but it doesn’t need to be to work in an emergency situation where understanding is more important that accuracy.”

WORKSHOPPING IT

Despite these collective efforts at CLSP and tremendous progress across the field in general, language processing remains a complex, evolving landscape with many unanswered questions and areas of opportunity. The challenges are so vast, in fact, that Khudanpur has added the role of convener to his already-considerable duties. Since 1995, the CLSP has been bringing together like-minded researchers and professionals from around the language processing world for the Frederick Jelinek Summer Workshop in Speech and Language Technology.

In these on-site, in-person workshops, teams of experts engage in a friendly competition to tackle the thorniest challenges and most promising unexplored avenues in the field.

“We get the best people in the world together for two months every summer to wrestle with some big problems,” Khudanpur says. “Together, we can accomplish in two months three to four years of progress.”

The workshop, named in honor of the former leader of CLSP, Frederick Jelinek, and traditionally located in Baltimore, will be held this summer in France on the campus of Le Mans University.

“It's dream-team thinking in a work-hard, play-hard environment populated by 40 or so leading experts from academia and industry,” Khudanpur says. “It’s great fun, but also there is a lot of serious work getting done.” ■

From the Mouths of Babes

One curious phenomenon emerging from such intense study of languages is that all these carefully trained voice recognition and transcription algorithms often fail when the speaker is a child. Paola Garcia-Perera, assistant research scientist in CLSP, came to understand this well when she was doing diarization of children’s speech for use in child psychology research. Diarization involves recording and transcribing children’s speech for hours at a time to search for clues as to how children think, learn, and interact with the world.

Time and again, Garcia-Perera noticed that the resulting transcriptions were not very good; in fact, they were often unusable. Part of the challenge is a technical one, having to do with the difficulty of recording clean audio from a child running about and playing. But there is also an inescapable linguistic element, something in the children’s speech patterns that was tripping up the voice recognition algorithms.

“Children’s speech patterns are different enough to fool the machines,” Garcia-Perera says. “The voice recognition systems that we had were failing, because when a child speaks, they elongate, repeat, and sometimes skip words, or their grammar is still developing.”

Through much trial and error, Garcia-Perera has been able to improve the transcriptions only to be confronted by a challenge of a different sort. Half the world’s population is bilingual. Many bilingual children often engage in “code switching”—moving effortlessly between two languages, mid-sentence.

Accurately transcribing code-switching requires a combined technique called language derivation where the algorithm must determine which language the child is speaking word by word to improve results.

“I think derivation technologies could have broader application in places like Africa, India, and Singapore where the people speak more than one language,” Garcia-Perera says.

BUGGING OUT!

STORY BY LISA ERCOLANO AND STAFF
ILLUSTRATIONS BY TRACI DABERKO

INSECTS AND ARACHNIDS INSPIRE CRUCIAL RESEARCH ACROSS THE RESEARCH ECOSYSTEM AT JOHNS HOPKINS—FROM ROBOT DESIGN TO TUMOR TRACKING.

From the classic 1950s science fiction film *Them!* to last year's *Jurassic World Dominion*, bugs have long been portrayed as threats to humankind's existence. It's easy to see why: There are more than 10 quintillion insects and arachnids on Earth—1.4 billion of them for every one of us. Let that sink in!

The truth is, life as we know it wouldn't exist without bees, flies, spiders, ticks, beetles, and the more than 900,000 other bug species that share our planet. Without their work pollinating crops, serving as food for birds and other animals, and breaking down and recycling soil nutrients, our ecosystem would simply collapse.

But these creatures also play a crucial role in the research ecosystem at Johns Hopkins, from inspiring the design of robots and other mechanical systems to lending their unique chemistry to medical diagnostics and treatments. Here we spotlight a few of these projects.

LIGHTING THE WAY TO BETTER MEDICAL TREATMENTS

Fireflies belong to the summer, floating above lush green lawns like a glowing galaxy come to Earth to illuminate warm evenings.

But in a laboratory on Johns Hopkins' East Baltimore campus, the winged beetles—or at least, the enzyme that makes them glimmer and shine—are lighting the way to better treatment for everything from cancer to tissue damaged by amyotrophic lateral sclerosis, also known as Lou Gehrig's disease.

"We use stem cells to treat and understand a number of ailments, and it's important for us to be able to track and follow these cells once they are in the body. Luciferase, the enzyme that makes fireflies glow, lets us do that," says Ana Rosu, a senior biomedical engineering major working in the lab of Jeff Bulte, an affiliate in the Johns Hopkins Institute for NanoBioTechology and faculty member at the Johns Hopkins University School of Medicine.

Fireflies (also called "lightning bugs") use luciferase, another chemical called luciferin, oxygen, and ATP (energy-carrying molecules found in all cells) to kindle light in specialized organs located in their abdomens so they can communicate with each other and find mates.

Rosu and Bulte's team leverages that chemical reaction by injecting stem cells that contain luciferase into animal models and following up with a chaser of luciferin, causing the original cells to illuminate. Then the researchers use sensitive optical imaging instruments to follow these cells, beaming like infinitesimal car headlights navigating a dark roadway, on their journey throughout the body.

"Because only live cells can oxidize luciferin and produce light, we can use the light imaging signal as a surrogate marker for cell survival to answer the two important questions: how long our injected cells survive, and when [targeted] tumor cells are starting to die," Rosu explains.

This is crucial information in the team's investigation into Lou Gehrig's and other diseases that cause damage to the myelin: the protective sheath surrounding nerve fibers in the brain, eyes, and spinal cord.

"Sometimes, stem cells are rejected by the host, so we need to give immunosuppressants. But it is important to optimize treatment protocols so the stem cells that are there as therapy can survive as long as they can. So we use the luciferase chemical reaction on various days, allowing us to see how long the therapeutic stem cells survive," Rosu says.

The team is also using stem cells to deliver gold and bismuth nanoparticles to tumors, which can kill the cancerous cells. Once the cells arrive, the researchers apply a laser to heat up the particles, "frying the tumor," Rosu notes.

"So what we do is engineer the tumor cells with luciferase before we implant them, and then we inject luciferin daily afterwards to see how many cancer cells—if any—survive," she says.

—L.E.

MOVE OVER, CHARLOTTE: THERE'S ANOTHER SPIDER IN TOWN

Mechanical engineering doctoral student Eugene Lin has a confession: Spiders used to make him shiver, especially big, hairy, scurrying ones.

But these days, one of Lin's closest companions is a 10-inch, thick-legged robotic spider that crouches on a web fashioned from parachute cord, waiting patiently for humans to activate the controller that will bring it to life.

This cyborg arachnid, modeled on *Uloborus diversus*—an orb-weaver common to the U.S.—may hold the key to understanding the complex vibrational system spiders use to sense and capture their prey: knowledge that could one day enable the design of machines, such as autonomous vehicles, with similar sensing abilities.

"The first step is understanding the spider's sensing. This kind of spider is essentially blind, so how does it locate and grab its prey? That little robot up there is helping us find out," says Lin, who is part of the Terradynamics Lab team in Hackerman Hall, which is led by Chen Li, assistant professor of mechanical engineering.

The team designed and built the mechanical spider from the ground up, informed by a trove of data gleaned from the lab of collaborator Andrew Gordus, an assistant professor of biology in the Krieger School of Arts and Sciences. Gordus studies the behavior, neural circuits, and genetics of *Uloborus diversus* in hundreds of living specimens that are raised and reproduce in the campus greenhouse.

So why build a robot model of a spider when you could just walk across the quad and observe the real thing?

Lin explains that researchers like using robots as active physical models of organisms for many reasons, including that models can be manipulated and controlled in ways that living creatures cannot, enabling researchers to test various hypotheses. The models also allow researchers to measure many facets of a system simultaneously, which can be challenging in real biological systems. In addition, models are simpler and easier to study to discover general principles, he says.

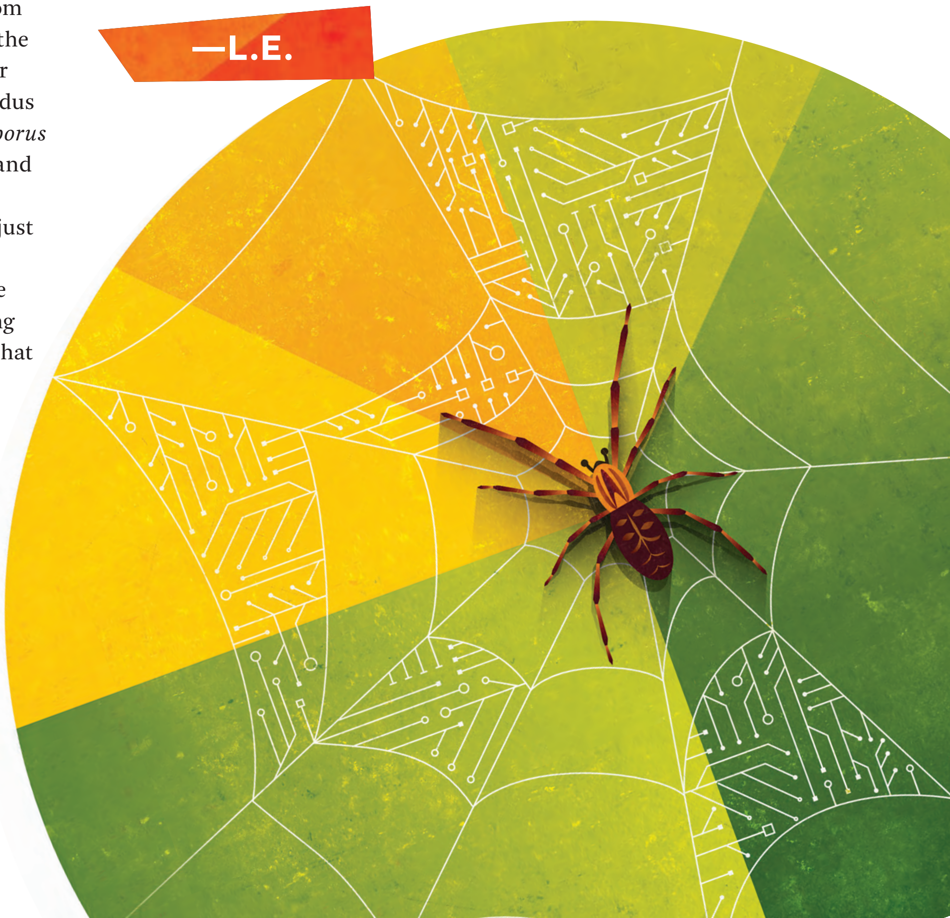
In the case of Lin's spider, the team not only can adjust the posture of the robot and the tension of the web, but also can record and analyze the robot's movements with two high-speed cameras that extract 3D coordinates of each location on the web to quantify how it is vibrating.

"What we've learned so far is that the behavior of the robotic spider and its robotic prey [a vibrating magnet clipped to a thread of the web] influences how vibrations propagate through the web and the legs of the robotic spider, but we still have a long way to go," Lin says.

First up may be adding a few more legs to the model. Right now it has only four.

"Yeah, that's next on our list," Lin says.

—L.E.



COCKROACHES AND THEIR MODEL BEHAVIOR

Encountered in pantries and kitchens, cockroaches are despised as ugly, unhealthy pests: something to be eliminated with a spritz of pesticide or the quick crush of a shoe heel. In the Terradynamics Lab on the Homewood campus, however, they are part of a research program aimed at developing robots that can traverse rough terrain as nimbly as the much-maligned insects can.

"In the wild, cockroaches are tenacious and can easily navigate dense vegetation and very complex terrain. If they tip over, they flip themselves back on their feet and just keep on going," says Chen Li, assistant professor of mechanical engineering and Terradynamics Lab director. "We are trying to understand how they do this, and then apply those principles to create advanced robots who can do the same."

Cockroach-inspired robots could, for instance, be deployed into post-earthquake rubble to perform search-and-rescue missions or explore the alien surface of another planet. To that end, Li's team uses cameras to closely track the movements of the bugs (in this case, *Blaberus discoidalis*, also known as the discoid cockroach because of its shape) as they traverse various terrains, from tracks featuring gaps and bumps to obstacle courses studded with tall, bendable plates mounted on springs that are designed to mimic blades of grass.

In a recent study, Li's team tracked how the insects transitioned between two types of movements—pushing, when the roaches shoved their bodies against the blades, so the blades gave way, and rolling, when the roaches spun into gaps between the blades to slide through. The researchers then digitally reconstructed the insects' and blades' 3D motion to examine how both movements looked on a landscape (which they call a "map") showing how the potential energy of both the creatures and blades influenced how the roaches' bodies moved.

"This landscape describes the combined effect of gravity and the beams' elastic bending forces acting on the animal body, just like a gravity field or electric field can describe forces acting on a point mass or charge," says Yaqing Wang, a doctoral student working with Li on roaches. "A key difference is that the roach is self-propelled by its legs, generating thrust, so instead of moving passively like a point mass or charge, it can actively propel itself on the potential energy landscape to traverse obstacles."

The team learned that transitioning from pushing to rolling is a move from one potential energy "basin" to another, requiring the roach to summon enough energy to overcome an energy barrier. They also discovered that the same potential energy landscape approach applies to understanding how roaches traverse other types of obstacles, and even to how they get back on their feet after flipping over.

Li says this new energy landscape approach clarifies how animals use physical interaction to transition between different types of movements and will assist in the design of robots that can better traverse complex 3D terrain like earthquake rubble and cluttered rocks on the moon or on Mars.

—various contributors

TRACKING TICK BITES

The woods are lovely, dark, and deep, but can harbor a menace: a tiny insect whose bite sickens almost half a million Americans a year. Lyme disease causes a range of symptoms that include fever, rash, and joint pain, as well as effects on the central nervous system and heart. Though it's common knowledge that *Borrelia burgdorferi*—the bacteria that causes the disease—enters the body through the bite of an infected deer tick, how the bacteria migrate from that bite into a person's bloodstream has not been clearly understood.

Led by Joseph R. and Lynn C. Reynolds Professor of Materials Science Peter Searson, a team of Johns Hopkins researchers may have found the answer. Using a custom-designed 3D tissue-engineered model, they learned that *B. burgdorferi* uses tenacious trial-and-error movements to find and slip through tiny openings called junctions in the lining of blood vessels near the original bite site. This allows them to hitch a ride on the bloodstream throughout the body, potentially infecting other tissues and organs. Their results appeared in *Advanced Science*.

"Our observations showed that if the bacteria did not find one of these junctions on the first try, they continued searching until one was found," says Searson, a core researcher at Johns Hopkins Institute for NanoBioTechnology. "The bacteria spend an hour or two using this behavior to find their way into the blood vessels, but once there, they are in circulation in a matter of seconds."

The team injected its 3D model, which simulates a human blood vessel and its surrounding dermal tissue, with the bacteria, simulating a tick bite, and used a high-resolution optical imaging technique to observe its movements. They observed that though the tissue at the original bite site was an obstacle for the spiral-shaped bacteria to surmount, little effort was needed for them to penetrate the junctions and enter the bloodstream.

Lyme disease is prevalent in North America, Europe, and Asia, and though antibiotic treatments are effective, some patients experience symptoms that can persist for months, and, in some cases, years. The team says that understanding how *B. burgdorferi* spreads throughout the body could help inform treatments to prevent bacteria from the initial bite entering other tissues and organs.

"We also believe that the kind of human tissue-engineered model we created can be broadly applied to visualize the details of dynamic processes associated with other vector-borne diseases and not just Lyme disease," Searson says.

—Gina Wadas

FLYING HIGH: A FIRST FOR BRAIN RESEARCH

In the 1600s, French philosopher René Descartes said "I think, therefore I am." Almost four centuries later, how we think remains largely a mystery.

Can the brain of a baby fruit fly shed some light on that process?

A team of researchers from Johns Hopkins University and the University of Cambridge believes so. They recently completed a map of that infinitesimal organ—smaller than a poppy seed—a landmark achievement in neuroscience that brings scientists closer to a true understanding of the mechanism of thought.

The map is a detailed diagram tracing every neural connection in the brain of the larval insect, an archetypal scientific model with brains comparable to that of humans.

The work, likely to underpin future brain research and to inspire new machine learning architectures, appeared in *Science*.

"If we want to understand who we are and how we think, part of that is understanding the mechanism of thought," says senior author Joshua Vogelstein, an assistant professor of biomedical engineering who specializes in data-driven projects including connectomics, the study of nervous system connections. "And the key to that is knowing how neurons connect with each other."

The first attempt at mapping a brain—a 14-year study of the roundworm begun in the 1970s—resulted in a partial map and a Nobel Prize. Since then, partial connectomes have been mapped in many systems, including flies, mice, and even humans, but these reconstructions typically represent only a tiny fraction of the total brain.

Comprehensive connectomes have only been generated for several small species with a few hundred to a few thousand neurons in their bodies—a roundworm, a larval sea squirt, and a larval marine annelid worm.

This team's connectome of *Drosophila melanogaster* larva is the most complete as well as the most expansive map of an entire insect brain ever completed. It includes 3,016 neurons and every connection between them: 548,000.

"It's been 50 years, and this is the first brain connectome. It's a flag in the sand that we can do this," Vogelstein says. "Everything has been working up to this."

The team chose the fruit fly larva because the species shares much of its fundamental biology with humans, including a comparable genetic foundation. It also has rich learning and decision-making behaviors, making it a useful model organism in neuroscience. And for practical purposes, its relatively compact brain can be imaged and its circuits reconstructed within a reasonable time frame.

Even so, the work took the University of Cambridge and Johns Hopkins 12 years. The imaging alone took about a day per neuron.

In the end, the full team charted every neuron and every connection and categorized each neuron by the role it plays in the brain. They found that the brain's busiest circuits were those that led to and away from neurons of the learning center.

The methods Johns Hopkins developed are applicable to any brain connection project, and their code is available to whomever attempts to map an even larger animal brain, Vogelstein says.

"What we learned about code for fruit flies will have implications for the code for humans," Vogelstein says. "That's what we want to understand—how to write a program that leads to a human brain network."

—Jill Rosen

The Solution Builders

Whether they share their vision on a flash drive or scrawled on a paper napkin, engineering faculty and students know they can count on experts in the Whiting School's Machine Shop to bring ideas to life.

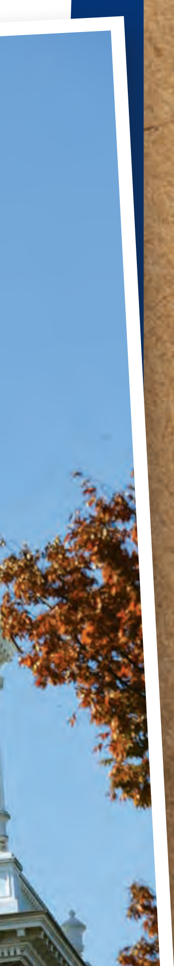
Written By **MONICA LEIGH**
Photos By **WILL KIRK AND MONICA LEIGH**

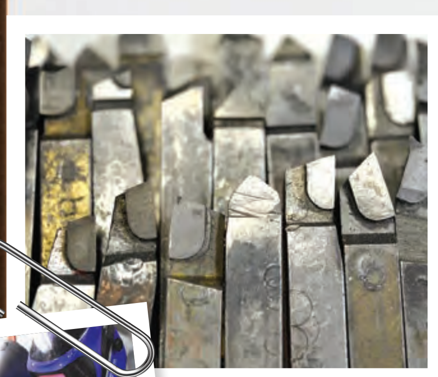
Photo courtesy Gurumurthy "Ram" Ramachandran.

Professor Gurumurthy "Ram" Ramachandran and his team in the Department of Environmental Health and Engineering faced some daunting challenges when they set out to build an environmental chamber to simulate workplace settings.

Their goal was to replicate industrial tasks that generate chemicals, fumes, and dusts to measure their airborne concentrations. To do that, the researchers would need to be able to control the rate of air flow in the chamber over a wide range and easily clean its surfaces between uses. And the entire facility would have to be constructed as an airtight space within the confines of their existing lab at JHU's Bloomberg School of Public Health.

Needing guidance and expertise, Ramachandran and his team did what countless other engineering faculty members and students at Johns Hopkins do: They visited the Whiting School's Machine Shop. Located in the basement of the Homewood campus' Wyman Park Building, the shop is a beehive of activity where saws buzz, drills whir, and sparks fly. It's here that a team of nine machinists, engineers, instrument designers, and others help university affiliates with consultation, design and manufacturing, and services and repair.





For Ramachandran's project, Machine Shop engineers suggested materials for the walls that would be easy to clean and would be inert to the various chemicals and conditions being tested, and working with the building's managers, they were able to tie into the existing ventilation and drainage systems.

"They were very thoughtful about every aspect. In fact, one of my favorite details was that one of my students suggested calling the chamber 'The Chamber of Exposures,' after Harry Potter's *Chamber of Secrets*." The shop's engineers clearly enjoyed the comparison and surprised Ramachandran and his students by creating a sign for the external wall, written in a Harry Potter-style font.

A Decade of Ideas

In 2008, when Rich Middlestadt joined Johns Hopkins Engineering as a machinist in the Department of Mechanical Engineering, he quickly became aware of student and faculty members' ever-growing need for assistance with conceptualizing, designing, and creating innovations that would enable them to address complex engineering problems, as well as inefficiencies that he observed that made it challenging to provide such support in an effective and efficient manner.

"I realized there was a disconnect between the departments. Each had their own resources and facilities to handle their own needs," he says.

From that need, WSE Manufacturing was born, with Middlestadt as its founding director. Today, the facility encompasses a machine shop, a student self-service facility (p.29), and a makerspace (p. 31), all of which provide the Engineering School and the JHU community with consultation and manufacturing services and access to equipment and resources.

Daren Ayres, senior instrument designer who has been with the Machine Shop since it opened in 2013, explains, “You never know what sort of request will walk through the door.” He has worked on projects ranging from repairs to the Gilman clock tower’s hands to lifesaving medical devices.

“Right now, I’m milling these little chambers that grow human tissue.” He holds up a clear Lucite rectangle about one inch thick and the size of a credit card. He is drilling tiny holes into its sides where he’ll insert minuscule rubber O-rings—about the size of the “o” on this page—to form a vacuum-sealed chamber in its center.

Rich Middlestadt

“I realized there was a disconnect between the departments. Each had their own resources and facilities to handle their own needs.”

– Rich Middlestadt, director, WSE Manufacturing

The devices, called bioreactors, are being made for Danielle Yarbrough, a third-year PhD student in the Department of Chemical and Biomolecular Engineering, whose team is investigating how different tissue engineering models are affected by space flight. In 2021, the Machine Shop created the first bioreactor, designed by Chelsey Dunham, a former postdoctoral fellow in the lab, and they have made eight more since.

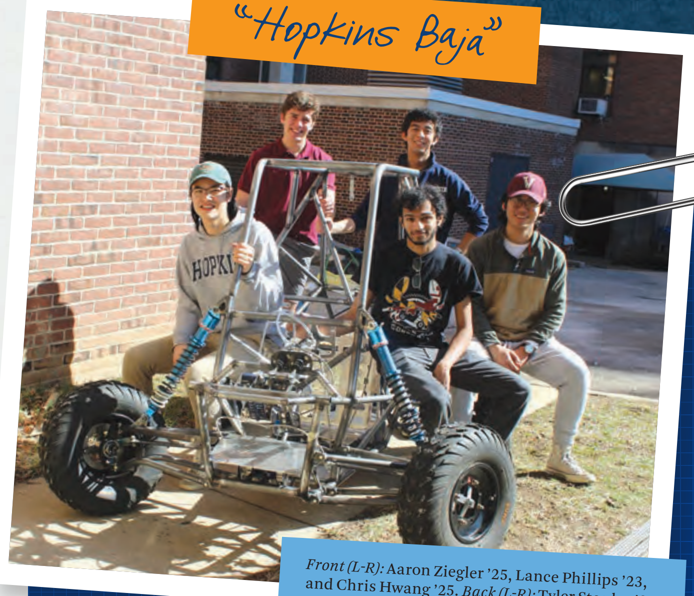
The bioreactors enable Yarbrough to grow models of human blood vessels, using a process that involves inserting two needles into the hollow port at the device's center into which she then inserts a tube of tissue tied to a polymer scaffold.

"We're studying how cells respond to different disease conditions with the goal of modeling various cardiovascular diseases," explains Yarbrough. "Currently, we either look at cells in a dish or use a mouse model, so this is an in-between way, or an in-vitro culture system, to study effects on actual human cells."

The ultimate goal of the project, which is funded by a branch of NASA's Human Research Program, the Translational Research Institute for Space Health, is determining a way to protect astronauts from radiation and understand the effects of deep space travel on the cardiovascular system.

Boundless Ingenuity

"The geniuses on campus have befriended the machinists and bring us ideas—whether on a flash drive or a paper napkin," says Cindy Larichiuta, the Machine Shop's program administrator. "We are like a chameleon who is constantly changing its colors to adapt to anything they need. We touch everything under the university umbrella—from the newest breakthrough for surgery to a refrigeration



"Hopkins Baja"

Front (L-R): Aaron Ziegler '25, Lance Phillips '23, and Chris Hwang '25. *Back (L-R):* Tyler Stanley '25 and Zatara Nepomuceno '25.

///SELF-GUIDED INNOVATORS///

IN THE SELF-SERVICE MACHINE SHOP, OPEN 24/7, STUDENTS HAVE ACCESS TO A FULL RANGE OF EQUIPMENT THEY NEED TO BRING THEIR PROJECTS TO FRUITION.

ONE GROUP THAT RELIES ON THIS SELF-SERVICE SHOP IS BLUE JAY RACING, AN UNDERGRADUATE TEAM THAT TAKES PART IN COMPETITIONS SPONSORED BY BAJA SAE, AN INTERNATIONAL ORGANIZATION THAT CHALLENGES STUDENTS TO BUILD FROM SCRATCH A VEHICLE THAT CAN WITHSTAND THE SEVERE PUNISHMENTS OF ROUGH TERRAIN, MUD, AND WATER AT SPONSORED EVENTS ACROSS THE COUNTRY.

LANCE PHILLIPS, A FOURTH-YEAR MECHANICAL ENGINEERING STUDENT, IS THIS YEAR'S TEAM LEAD. "BEING IN BAJA HAS GIVEN ME HANDS-ON, REAL-WORLD ENGINEERING EXPERIENCE THAT I WOULDN'T HAVE NECESSARILY GOTTEN IN THE CLASSROOM. I HAVE LEARNED TO WELD AND TO USE SUBTRACTING MANUFACTURING MACHINES, LIKE MILLS AND LATHES," HE SAYS. "MY FIRST INTERNSHIP WAS THE DIRECT RESULT OF PARTICIPATION IN THIS CLUB."

THERE ARE ABOUT 25 PEOPLE ON THE TEAM THIS YEAR. THEY PLANNED THEIR DESIGN LAST SUMMER, HAVE BEEN BUILDING THEIR VEHICLE THROUGHOUT THE SCHOOL YEAR, AND THIS SUMMER WILL COMPETE AGAINST APPROXIMATELY 200 TEAMS REPRESENTING UNIVERSITY ENGINEERING PROGRAMS FROM 14 NATIONS.

Daren Ayres

"You never know what sort of request will walk through the door."

– Daren Ayres, senior instrument designer

unit that needs to be moved across campus—because we have the expertise and resources to do both."

Mark Cooper, a senior instrument designer, also appreciates the variety of projects. "One of my favorite things about working here is that you never know what ideas these engineers are going to come up with. And they often have no idea how to make what they have conceptualized. That's where we come in," Cooper says.

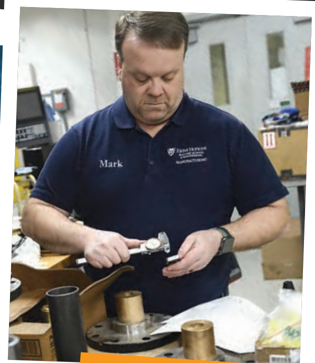
One of Cooper's first projects was made at the request of a researcher studying water droplet deviations in a controllable-strength electromagnetic field. The researcher needed a voltage field plate system that would enable him to understand the effects of strength of electromagnetic field on varying droplets per second. Cooper's solution was to build a stand with two copper plates that could swing out at increasing increments of rotation to adjust the distance between them while 5,000 volts of current ran through them and water droplets dripped through the field.

"The challenge in this case was connecting wires to copper plates that would conduct electricity—with water—and not get electrocuted or set anything on fire," Cooper says.

Stipe Iveljic, a senior instrument designer, is known by his peers as the master of tiny things. For instance, he machined a small bone-mounted marker that can be screwed into place and is used to measure the precise 3D location and angle of a spinal vertebra during scoliosis surgery.

The device was a key component of a technology developed by Spine Align, a local startup from the Whiting School's Center for Bioengineering Innovation and Design, led by master's students Amir Soltanianzadeh MS '18 (CEO and co-founder) and David Gullotti MS '17, MD '19 (SOM) (CTO and co-founder, now interventional radiology resident), and Nick Theodore (co-founder and director of the Neurosurgical Spine Center at Johns Hopkins Hospital).

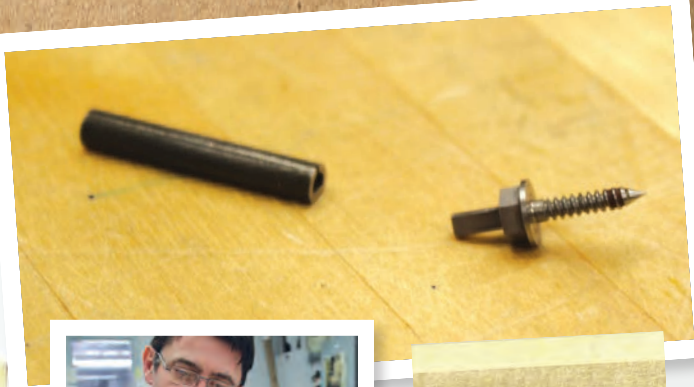
Photo courtesy Rich Middlestadt.



Mark Cooper

"One of my favorite things about working here is that you never know what ideas these engineers are going to come up with. And they often have no idea how to make what they have conceptualized. That's where we come in."

– Mark Cooper, senior instrument designer



Stipe Iveljic

"I truly enjoy helping students and faculty with research that might lead to developing new medical devices or procedures."

– *Stipe Iveljic, senior instrument designer*

"Having the right equipment here in our shop makes this challenging job a little bit easier for me," says Stipe. "I truly enjoy helping students and faculty with research that might lead to developing new medical devices or procedures."

Room to Grow

One result of WSE Manufacturing's success, ironically, is that the team has outgrown its original space in the Wyman Park Building. Due to space restrictions and ventilation requirements, they have some facilities in other buildings. A pending renovation to the Wyman Park Building may enable them to double—or even triple—in size and consolidate operations with the Machine Shop at its center, once again giving form to Middlestadt's vision.

Regardless of where the shop is located, it will continue to serve its purpose: offering engineered solutions for people across the university. ■

///WHERE IDEAS SHINE///

THE MAKERSPACE, A MANUFACTURING AND DESIGN SPACE MANAGED BY THE WHITING SCHOOL, IS THE GO-TO HUB FOR INNOVATIVE PROJECTS OF ALL KINDS. SERVING ALL JOHNS HOPKINS UNIVERSITY AFFILIATES, IT IS OUTFITTED WITH 3D PRINTERS, VINYL AND LASER CUTTERS, AN ELECTRICAL STATION, AND MORE.

THIS YEAR, THE FACILITY WAS USED FOR A SEMESTER-LONG TEAM PROJECT TO CREATE PERSEPHONE: FOUR SEASONS, AN INTERACTIVE LIGHT AND SOUND ORGAN CREATED FOR THE ANNUAL LIGHTING OF THE QUADS CEREMONY IN DECEMBER. THE FACILITY'S FIRST-EVER PARTNERSHIP WITH JOHNS HOPKINS UNIVERSITY'S DIGITAL MEDIA CENTER, THE TEAM WAS LED BY MAKERSPACE MANAGER LUKE IKARD, AND JASON CHARNEY, MULTIMEDIA SPECIALIST FOR THE DIGITAL MEDIA CENTER.

THE INTERACTIVE SYNTHESIZER RESEMBLED A PIPE ORGAN, WHICH PRODUCES COLUMNS OF LED LIGHT THAT CORRESPOND TO EACH KEY. INSPIRED BY THE MYTH OF PERSEPHONE AND THE CHANGING OF THE SEASONS, THE LED COLORS AND MUSICAL MODES EVOLVE AS THE INSTRUMENT IS PLAYED.

"JASON LED THE TECHNOLOGY ASPECT OF THE PROJECT," IKARD SAYS. "WE WORKED WITH THE STUDENTS TO DEVELOP THE PHYSICAL STRUCTURE AND HOW WE WANTED USERS TO INTERACT WITH IT. THAT'S WHERE THE MAKERSPACE SHINES; WE HAVE LARGER PROTOTYPE MANUFACTURING EQUIPMENT THAT CAN PRODUCE ON THIS SCALE. WE USED OUR WOODSHOP AND OUR CNC ROUTER TO IMPORT 2D DESIGNS AND CUT THEM PERFECTLY OUT OF PLYWOOD. BEING ABLE TO DESIGN THAT KIND OF CUSTOM OBJECT IS WHAT WE EXCEL AT."

THE LIGHT ORGAN WAS SHOWCASED AT THREE CAMPUS EVENTS THIS YEAR: THE LIGHTING OF THE QUADS, A NIGHT AT THE ICE RINK, AND THE ALUMNI WEEKEND ARTS SHOWCASE.

—Koye Berry

Top row (*from left to right*): Jonathan Wu, Daniel Lewis, Eric McAlexander, Alice Yu.
Bottom row (*from left to right*): Mariah Snelson, Selena Shirkin, Ayeeshi Poosarla, Gloria Kalnitskaya.

A New Device for Fetal Therapy

EVERY YEAR, 120,000 BABIES ARE BORN IN THE UNITED STATES WITH BIRTH DEFECTS, according to the Centers for Disease Control and Prevention. The good news is that emergency in-utero surgery can repair severe congenital disorders before a baby is born.

But such surgery—a minimally invasive, ultrasound-guided procedure involving accessing the uterus via a port inserted through the mother's abdomen—carries risks, including that of membrane rupture, which occurs in 30% to 40% of all patients.

The high rate of such surgical complications motivated biomedical engineering third-year student Selena Shirkin to tackle this real-world health care challenge. She already had some experience in the medical technologies industry: Her earlier work on Stetpulse, a tool to sterilize stethoscopes during clinical practice, received funding from VentureWell, a higher education network. So in the spring of her sophomore year, she began leading a team to design a better solution for fetal therapy.

Shirkin and her team quickly zeroed in on preventing membrane rupture. "This is when the amniotic fluid leaks out into the space between the uterine wall and the amniotic membrane," she says. "That causes the membrane to strip off, like wallpaper peeling off a wall. And that causes the mother's water to break, leading to preterm labor." Since most surgical interventions take place before 25 weeks of gestation, membrane rupture can have serious consequences, including the death of the prematurely born baby.

During their research phase, Shirkin and her team learned that the main cause of membrane rupture is the use of devices not specifically intended for fetal surgical therapy—oversized and often dull instruments that were designed for cardiovascular, laparoscopic, and other endoscopic surgeries.

"Our goal is to create a new access port system specifically for the uterine environment," says Shirkin. "It would be inserted into the mother's womb and function as a tunnel into the uterus."

Working in collaboration with Ahmet Baschat, director of the Center for Fetal Therapy and his team of maternal-fetal medicine specialists at the Johns Hopkins University School of Medicine, the student team developed a novel port system with two parts: a sharper introducer needle, also known as an obturator, that would pierce through layers of tissue, including the uterine wall, without causing membrane rupture; and a port sheath that would radially expand, allowing surgeons to insert varying sizes of instruments into the uterus. The device is currently in the prototype stage.

"My goal is to push this project as far beyond the classroom as I can," says Shirkin. "I think we can really make a difference."

— NIKOLAS CHARLES

THIS PAGE AND OPPOSITE PAGE: WILL KIRK/HOMEWOODPHOTO.JHU.EDU; OPPOSITE PAGE ILLUSTRATION: COURTESY OF ROBERTO FLORES.

Dan Keplinger

"Working with the students lets me see new ways to do things, and the new crown will make my life a bit easier."

— DAN KEPLINGER

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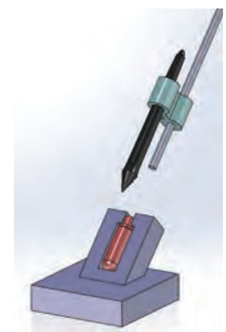

stylus mode

A Design for Freedom

IT MAY LOOK LIKE A SIMPLE CONTRAPTION OF NYLON STRAPS, MOLDED POLYCARBONATE STRIPS, and foam padding, but to a local artist, it represents so much more: a voice, the ability to communicate thoughts and ideas, and freedom of expression.

"Art gives me a way to express myself without anybody interpreting for me," says Dan Keplinger, whose severe cerebral palsy prevents him from both speaking intelligibly and from using his hands to create the art that is his living and lifeblood.

Instead, his stylus and paintbrushes are held by a carbon-fiber rod mounted on a "crown" strapped around his head and under his chin, allowing him to use head movements to create impressionist figurative works of art that have been exhibited in shows from New York to San Francisco.

Though Keplinger has used a similar device to paint and draw since he discovered his prodigious talent in high school in the 1990s, the current version—which includes high-tech features aimed at enhancing its ergonomics and functionality—was created by a team of Johns Hopkins engineering students who are part of the university's Volunteers for Medical Engineering group.

Led by senior mechanical engineering student Roberto Flores, VME members worked with the Image Center of Maryland, a nonprofit that pairs area residents dealing with disability challenges with volunteer engineers who create devices aimed at enhancing their independence.

"Dan's crown is one of three projects we tackled this year," says Flores. "It had major issues after years of being used for hours a day, and we provided some improvements."

Those upgrades included not only making the crown more durable and comfortable—the chin strap was so loose that the artist had to work with his mouth open, so his lower jaw held it in place—but also customizing it to hold the stylus required for use with a touchscreen. When the student team first met the artist, his stylus was attached with paint-splattered masking tape.

Keplinger asked for the ability to easily add (or remove) a pencil eraser to the stylus tip so he could shift between creating art and typing on his keyboard. (Typing without a tip could damage the stylus.)

"Before, he would try to use his hands to hold the eraser and move his head to manipulate the stylus to get it on the end. Sometimes, it would fall, and he couldn't retrieve it," says team member Melody Lei, a senior mechanical engineering major and project lead.

The team's solution was to create a 3D-printed plastic base that is mounted on the artist's desk and holds the eraser. Keplinger uses his head to direct the stylus into the base, snapping the eraser on and off as needed.

"Working with the students lets me see new ways to do things, and the new crown will make my life a bit easier," says the artist.

— LISA ERCOLANO

Chinat Yu

WHEN CHINAT YU'S PEERS WERE SETTLING IN ON THEIR FIRST YEAR AT HOPKINS, HE WAS HANDING out old-school fliers inviting students to a game so they could get to know one another. "I said, 'Hey, nice to meet you! I created this treasure hunt. Do you want to play?'" recalls Yu, now a senior majoring in computer science. "The treasure hunt accelerated my assimilation into Hopkins. I felt a sense of community right away. It exposed me to so many different people."

Yu, who was born and raised in Hong Kong, would go on to join an a cappella group, get elected to the Hopkins Student Government Association, and create a popular podcast series that helps others feel more connected.

Hopkins Hacks, which he launched at the end of his junior year, offers interviews with faculty, alumni, and students, in which he asks them to share their definition of a successful Hopkins experience. The conversations touch upon the four pillars of college life: work, relationships, health, and play, as interviewees explain how they utilize the university's resources.

"I connected with faculty and students like I never had before, talking for an hour about deep aspects of their lives," says Yu. Encouraging others to share their personal triumphs, challenges, and insecurities with an audience of fellow high achievers felt like the right direction, he says, especially in the wake of the pandemic.

The idea for *Hopkins Hacks* came after a time of personal loss for Yu. His two grandfathers died a week apart, and soon thereafter he lost the election for senior class president by six votes.

"I realized that what I really cared about wasn't being president but how I could meaningfully engage the communities around me," he says. Throughout his campaign, he "was advocating for mental health and international student representation, and with the show, [I realized] there were more ways I could help."

In fact, many of the episodes of *Hopkins Hacks* touch on issues surrounding wellness, including his own experiences. In one two-part series, he even put himself "on the hotseat," being interviewed by chief editor Resham Talwar, a sophomore biomedical engineering major. "[People are] surprised by how honestly we talk about mental health on the podcast because of the stigma," says Yu. "I'm radically transparent, whether it's about my mental health or my work. I share ideas, and I don't worry about people stealing them. If someone else can solve a problem, great."

As a first-year student at the height of the COVID-19 pandemic, Yu joined a multidisciplinary team to help develop an augmented reality phone app, Quest2Learn, which allows students to do experiments on smartphones, even without access to lab equipment. Yu became the project lead. In 2020, his team applied to the university for a DELTA grant (a fund for digital education initiatives) but didn't land one. Most of the team moved on. Yu, who was in Hong Kong, and three others stuck with it, rebuilt a team, reached out to a professor for help, and eight months later had a prototype.

"Our project became a course and with our professor guiding us, we were able to push out our first iOS version. We applied for the DELTA grant again and got it in the summer of 2021," Yu says. "It took a second try, but failure is an opportunity for growth. We've had more than 400 students using

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

"I'm radically transparent, whether it's about my mental health or my work. I share ideas, and I don't worry about people stealing them. If someone else can solve a problem, great."

— CHINAT YU

our app, and we've expanded it into Hong Kong and Baltimore-area schools."

The Quest2Learn work helped Yu land an internship with Microsoft this summer in Seattle. In the fall, he will pursue a master's in learning design and technology at Stanford. His long-term vision for education? "How can we inspire the flame in each student? I see the future as less about standardized exams and more about project-based personalized work. I hope to spearhead that change," he says.

Technology aside, basic connection will always hold value. Yu saved the sheet of participants from his freshman-year treasure hunt. Some of the prize-seekers became lifelong friends, student government collaborators, and Quest2Learn coworkers. "I'll always be part of the Hopkins community," he says, "and I want to give back."

— JULIE WEINGARDEN DUBIN

Bella Hunt

Better Optics

BELLA HUNT'S GRADUATE RESEARCH INTO CHALCOGENIDES, A CLASS OF MATERIALS USED FOR MEMORY STORAGE, HAS GOTTEN A BIG BOOST, THANKS to a $100,000 award from the Johns Hopkins University Applied Physics Laboratory.

Hunt is a fifth-year doctoral candidate in the Department of Materials Science and Engineering. Her project amorphizes, or crystallizes, chalcogenides to create meta-optics: a new kind of lens technology with sensing and imaging capability. She is working to create an amorphous optic that can then crystallize different areas, changing the meta-optic's functionality. The project has various potential applications, including use in space to change the focal length of a lens using a laser, thereby lessening the need for multiple lenses to view points at different distances.

"Think like CDs. You laser write CDs by amorphizing or crystallizing that material. We are using that same method to create a meta-optic. This is done by selectively transitioning regions either to an amorphous state or to a crystalline state by tuning different parameters, such as which regions are crystallized," says Hunt, who works part-time at APL.

— JACK DARRELL

Mohan B. Dangi *(left)*

Taking Garbage Out of the Streets

WHEN MOHAN B. DANGI PHD '09 BEGAN TRAVELING TO NEPAL IN 1998, HIS GOAL WAS TO HELP DEVELOP a renewable-energy curriculum for the nation's K-12 schools, to create an environmental engineering degree for national universities, and to assist the newly established Alternative Energy Promotion Center.

Returning to his native country representing U.S. National Renewable Energy Laboratory to share his growing expertise, he says, was a dream come true.

But on one trip, while walking in the capital city of Kathmandu, Dangi noticed something: Alongside the medieval-era houses were piles of garbage left to putrefy in the streets, attracting bugs and mice. He decided to change focus.

"Yes, developing a curriculum is important, but what's more important is doing something about this garbage," Dangi remembers thinking. He wanted to find a solution that would address the problem, not just in Nepal, but in any developing country.

This brought him to the Whiting School of Engineering's geography and environmental engineering program, where he learned to solve complex issues at the intersection of engineering, public policy, economics, and culture.

"Solid waste is a global problem, but it demands a local solution," he says. "What works in the mountain communities of Colorado may not work in the mountain communities of Nepal."

To deepen his understanding of how solid waste was being generated at the local level, Mohan applied sampling tools used by his professors in the Bloomberg School of Public Health: He identified the wards of Kathmandu by their residents' income brackets, and then systematically visited each one to collect random samples of the garbage a household produced over two weeks. From there, he used this data to inform government leaders about how and why waste had become a problem.

It's a technique he's since replicated in other developing world cities, earning him international recognition in the form of two Fulbright Awards, a Jefferson Science Fellowship at USAID, and an Embassy Science Fellowship from the U.S. Department of State.

And the need for his work only increases. Solid waste is expected to grow from 2.01 billion metric tons to 3.4 billion metric tons by 2050, with the largest increase generated in lower- and middle-income countries. Though this work has kept Dangi busy for more than a decade, he says he still feels like a student as he travels to survey new countries and learns from the locals.

"I'm the first one who goes out and speaks with community members when we do these surveys," he says. "That's what I really enjoy, working with the locals and learning how they do things."

— ELENA CONWAY

THIS PAGE: PHOTO COURTESY OF MOHAN DANGI.

Making Earth a Better Place

SPACE SYSTEMS EXPERT MICHAELYN THOMAS MS '21 EMBRACES THE POTENTIAL OF USING SPACE FOR good. In January 2022, she joined the U.S. Space Force—the Armed Forces' newest branch created to organize, train, and equip space forces to protect U.S. and allied interests in space.

As deputy director of the Resilient Missile Warning, Tracking, and Defense Acquisition Delta, Thomas, a civilian, oversees the technology maturation and systems engineering of the new acquisition delta. She also built the team with a diversity, equity, and inclusion mindset, and leads the $2 billion Medium Earth Orbit (MEO) Track constellation portfolio.

"My team is operating as a cross-organizational center of excellence to deliver and implement affordable and optimized solutions for mission assurance," says Thomas. "Space exploration initiatives transcend the divisions we often face on Earth, and through this innovative technology, we are all working together to make Earth a better place."

Before joining the Space Force, Thomas was a leader at Virgin Orbit, serving as head of affordability and executive program manager for global spaceport development. She also spent a decade at The Boeing Company's Satellite Development Center. There, she specialized in technical program management, business operations, and finance management.

In 2019, she decided to pursue a master's degree in space systems engineering through the Whiting School of Engineering's Engineering for Professionals program.

"I've led thousands of engineers, and it was time for me to solidify my engineering acumen," says Thomas, who graduated from the program with honors in 2021.

She's equally purposeful about embracing the potential of others. "Women are severely underrepresented in the space industry and technical positions. As I started to achieve more leadership positions—within the first 10 years of my career, I went from entry-level to reporting to the CEO at an aerospace firm—fewer people looked like me," she says. "As a woman of color, I felt it necessary to become the representation I desperately sought, as well as becoming a role model to others."

Thomas reaches children and adults worldwide through speaking engagements and her blog, Spaced Out Doc (spacedoutdoc.com), where she shares research and her experiences. She also volunteers for several organizations focused on expanding STEAM opportunities for women and people of color.

"My goal is to educate, motivate, and inspire as many [people] as possible in the space industry," Thomas adds. "Inclusive business is good business, and equity, diversity, and inclusion are the building blocks to space systems innovation. It takes each of our diverse experiences to create and deliver out-of-this-world space technology."

— SARAH ACHENBACH

Michaelyn Thomas

Punk Band with a Strong Work Ethic

Paul Vallejo

WHEN PAUL VALLEJO '19, MS '22, FIRST TALKED WITH fellow Hopkins undergrad Ashrita Kumar about forming a band in 2018, he expected music to be a hobby between classes. Five years later, their band Pinkshift has a studio album listed in entertainment magazine *Paste*'s best punk albums of 2022, and they're striking out on their second cross-country tour.

A chemical and biomolecular engineering major, Vallejo met Kumar through Homewood United for Music, a student group that connects musicians through events. Finding they shared musical tastes, they collaborated on cover songs before moving on to original music.

"At a certain point, we were like, 'Wow, we have six or seven songs here. We should probably start a band,'" he says.

They enlisted fellow undergrad Myron Houngbedji as their drummer after staking out the Mattin Center's drum room, and together played at any student event that would take a punk act—from the Mattin Center's Halloween party to the Inter-Asian Council's Disco Night. By the time Vallejo and Kumar entered their master's programs, Pinkshift was playing shows in Baltimore and D.C.

Although members of the band loved performing together, Vallejo admits that they expected to go their separate ways after graduation.

Then in summer of 2020, Pinkshift's new song, "i'm gonna tell my therapist on you," went viral, resulting in opportunities to open for more popular bands on tour: an offer the trio felt it could not pass up.

"We are all children of immigrants and grew up with financial sustainability as the key goal. None of us could conceive of making a living off of our music," says Vallejo. "But gradually, we started considering it and looked for ways to make it work."

Vallejo took a remote job at a sustainability consultancy firm that was willing to be flexible. After two years, he says they've finally settled on a routine that allows him to turn in reports for clients on an intermittent schedule, granting him more time to record music and play shows with the band. Balancing the two careers has been hard work that's paying off.

"I always admired Ashrita and Myron for their strong work ethic in everything they do, whether in academics or music," he says of his bandmates. "Hopkins required that kind of perfectionism, and after graduation, none of that has changed for us."

— EC

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What a Racket

Anne Albinak

The Racket is the band's informal name, but "because we're not the only racket in town," says Albinak, it has an official name as well: The Band Formerly (and Temporarily) Almost Completely Unknown as The Racket.

MANY ON THE HOMEWOOD CAMPUS KNOW ANNE ALBINAK, DIRECTOR OF RESEARCH ADMINISTRATION operations at the Whiting School, who has worked at Hopkins for 25 years. But not everyone knows she is the bass player in a band.

The Racket is the band's informal name, but "because we're not the only racket in town," says Albinak, it has an official name as well: The Band Formerly (and Temporarily) Almost Completely Unknown as The Racket. The group is made up of four musicians: Albinak and husband Doug Lay, Rod Rebuck, and David Selvin.

She has been with the band for 19 years. "I was dating Doug at the time," explains Albinak, "and they had a bass player who didn't show up for a few rehearsals. Doug said, 'I'll bet you can play bass. You should join the band.' I didn't play bass, but I thought, 'Huh, how hard could it be to learn the basics?' so I learned to play! I also play keyboards, guitar, drums, perform one trumpet song, and sing on various songs."

A classically trained clarinetist, Albinak attended the Peabody Conservatory before changing her focus of study to history. "I come from a musical family," she says. "Both my parents were in the Baltimore Symphony Chorus; my brother was the original drummer for Child's Play, a local '80s metal band; and my nephew attends the Berklee College of Music."

The Racket plays a few gigs per year, most recently at Restaurant 198 in Burtonsville, but mainly entertains family and friends when the players rehearse every Sunday on a stage built into the basement of Selvin's house with twinkly lights and a movie projection screen running in the background.

"We all have disparate tastes. We mostly play original songs with a few covers such as 'You're One' by Imperial Teen and 'Vitamin C' by Can," Albinak says. "I wrote a song called 'Precious,' which is best described as being for four guitars and one angry female. It's a nice creative outlet—not that my day job isn't; I consider problem-solving and spreadsheets to be creative—but it's a good contrast to financial research compliance and grants administration."

— MONICA LEIGH

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Young Science Aficionados

Some of Emily Sperring's best high school memories involve Science Olympiad, a series of regional, state, and national competitions challenging students on knowledge in areas ranging from engineering and chemistry to biology and Earth science.

So when she came to Johns Hopkins to study environmental health and engineering three years ago, she began to mentor Maryland Science Olympiad teams at nearby schools, including Barclay Elementary Middle School.

For an hour after school each week, Sperring guides the seventh- and eighth-grade students as they build balsa-wood bridges and gliders, scrutinize rocks and minerals, study the solar system, use forensics to solve fictional crimes, and more. The energetic eight-member team triumphed in the Maryland Science Olympiad's March regional competition, qualifying for the statewide event in April.

"It is incredible how passionate and motivated these children are," says Sperring. "But apart from their incredible performance as competitors, they love telling me about random cool science stuff, so I learn a lot from them, too."

Sperring is one of about 70 Johns Hopkins students mentoring Baltimore City students in STEM through the Charm City Science League this year. Mentors work with teams at a dozen city public schools, logging more than 1,500 volunteer hours.

— LISA ERCOLANO

Emily Sperring *(right)*