IMPACT

2019

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STARTING OFF

Welcome to the second annual issue of *Impact: Research at Brown*, and to the many stories of outstanding work by Brown faculty and students. We are building on many fronts in our research, in bricks-and-mortar structures and even more in relationships, and there is much exciting news to share.

Let's start in downtown Providence, where Brown is investing in a newly thriving entrepreneurial and research-intensive ecosystem that is supporting the University's ambitions in translational medical research, forging new industry partnerships, and much more.

It is home to the Warren Alpert Medical School, flourishing medical/biology labs, the School of Public Health, the Institute for Computational and Experimental Research in Mathematics, and, most recently, the South Street Landing building, which is inspiring collaboration between my office and hundreds of other key administrative staff consolidated there. Later this year, our growing School of Professional Studies will join the Jewelry District's new Innovation Center in a building developed by Wexford Science & Technology.

On College Hill, we dedicated the Engineering Research Center last May. This three-story, 80,000-square-foot structure has specialized research laboratories and collaborative spaces for biomedical engineering, advanced materials, environmental engineering, and other programs. In December, the Watson Institute for International and Public Affairs opened the doors to Stephen Robert Hall, an expansion designed to fuel an expanding community of scholars working on global policy issues.

The latest research hub is at 164 Angell Street, the state-of-the-art collaborative home of the Data Science Initiative, the Center for Computational Molecular Biology, the Carney Institute for Brain Science, and the Annenberg Institute for School Reform.

In this year's *Impact*, you'll read about research made possible by these Brown investments and by funding from federal agencies and foundations. The Carney Institute, newly named by an extraordinarily generous gift, is on the leading edge of advancing research in brain science toward cures and treatments for ALS, Parkinson's, and other neurological disorders and diseases. Continuing a proud tradition of excellence in particle physics, Brown researchers continue to make discoveries contributing to our understanding of the universe, and play leading roles in the multinational upgrade of the particle collider in Europe. The Center for the Study of Slavery and Justice marks its fifth year with an ambitious agenda. And our undergraduates are engaging in remarkable research projects, including creating EQUiSat, a small satellite deployed in July by astronauts on the International Space Station.

I hope that you enjoy this year's selection of stories and this glimpse of the depth and breadth of research and scholarship at Brown.

Jill Pipher
Vice President for Research
Elisha Benjamin Andrews Professor of Mathematics

IMPACT
RESEARCH AT BROWN

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On the Cover: A simulation of radiation emerging from a terahertz multiplexer. Terahertz is high-frequency radiation that could enable the next generation of ultra-high-bandwidth networks to handle more data. (Mittleman lab/Brown University/Ducournau Lab/CNRS/University of Lille)

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NICK DENTAMARO

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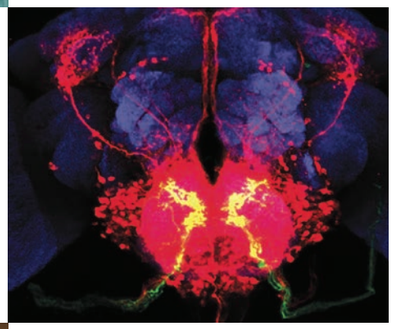


RESEARCH BRIEFS

A COMPENDIUM OF RECENT HIGHLIGHTS OF BROWN RESEARCH

Leslie Gordon '98 MD PhD with her son, Sam Berns, in 2005, when he was 8. He died in 2014.

LEAH FASTEN

Personal Medicine

A professor makes progress on a rare disease that claimed her son's life.

For Leslie Gordon '98 MD PhD, a professor of pediatrics at Brown's Warren Alpert Medical School and Hasbro Children's Hospital, medicine is especially personal.

Before he was two years old, her son, Sam Berns, was diagnosed with progeria, an extremely rare genetic disorder that causes premature aging and death. Sam, whose optimism in the face of the condition was chronicled in an HBO documentary, died at age 17 in 2014.

After Sam's diagnosis, Gordon shifted her work as a physician-scientist to focus on the disease, which affects approximately one in every 6 million infants born. Children with the condition currently live an average of 14.5 years and generally die due to rapid progression of heart disease. But in 2018, there was significant progress.

Gordon was the lead author of a *Journal of the American Medical Association* article suggesting an experimental drug therapy to extend the lives of children with progeria. Research showed that children with progeria who were treated with lonafarnib, a drug originally developed to treat cancer, were more likely to survive over the course of the study, compared with children with progeria who did not receive the drug. The results suggested a promising avenue for treating a condition for which there are currently no approved therapies.

"These results provide new promise and optimism."
—Leslie Gordon

In addition, the nonprofit Progeria Research Foundation announced a collaboration and supply agreement with a pharmaceutical company to test the drug—the first therapy submitted to the U.S. Food and Drug Administration for treatment of progeria. Gordon and her husband and fellow physician, Scott Berns, started the foundation and she is medical director.

"This study provides supporting evidence that we can begin to put the brakes on the rapid aging process for children with progeria," Gordon said. "These results provide new promise and optimism to the progeria community."

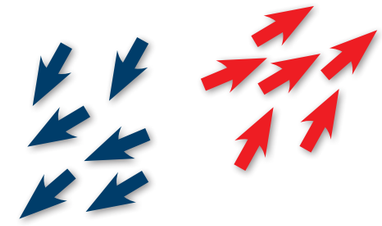
Don't Blame the Web

Growth of political polarization is largest for groups least likely to use Internet.

Political polarization in the United States? Don't just blame the web, says Brown economics professor Jesse Shapiro.

A popular narrative has developed that online news sources and social media circles create "echo-chambers" of like-minded individuals who paint the opposition as perpetrators of outrages and close off opportunities for conversation.

But Shapiro—along with two colleagues, Levi Boxell and Matthew Gentzkow of Stanford University—showed through data-driven research in an article published in the *Proceedings of the National Academy of Sciences* that growth in political polarization is actually largest for the demographic groups in which individuals are least likely to use the Internet and social media.



In addition, their analysis of web use among Republican voters in the 2016 presidential election revealed that Donald Trump performed especially well among those least likely to get political information online. That finding, published in the journal *PLOS ONE*, challenges claims that the web and social media drove the presidential election in favor of Trump.

"These findings don't prove that online campaign efforts and other aspects of digital media had no impact on the election," Shapiro said. "But they do pose a challenge for some conventional narratives that put those factors front and center."

Age was a major predictor of Internet and social media use, according to the research. Some 30 percent of those aged 65 and older used social media in 2016, in contrast to 88 percent of those 18 to 39 years old. Yet Shapiro and his collaborators found that, for seven of eight individual measures, polarization increased more for the older demographic than for younger Americans.

"The main culprits in explaining the rapid rise in polarization probably have to do with forces broader and deeper than the digitization of the news," Shapiro said.

ALUMNI IMPACT

ELLEN STOFAN ’85 ScM, ’89 PhD
WAS APPOINTED DIRECTOR OF THE NATIONAL AIR AND SPACE MUSEUM IN APRIL 2018, BECOMING THE FIRST WOMAN NAMED TO THE POST. SHE STUDIED GEOLOGY AT BROWN.

“My time at Brown challenged me to take all that I had learned as an Earth geologist and apply those same principles and techniques in a rigorous way to studying planetary surfaces. As planetary scientists, we always come back to applying what we learn elsewhere to understand our own planet better.”

SMITHSONIAN’S NATIONAL AIR AND SPACE MUSEUM; AGELESS INNOVATION

Creature Comfort

Scientists team up with toymakers to find new ways to aid older adults.

Older adults often need help with the challenging tasks of everyday living, and Brown cognitive and computer scientists are working to make smart robotic cats and dogs part of the solution.

With a $1 million grant from the National Science Foundation, Brown’s Humanity-Centered Robotics Initiative (HCRI) is teaming up with researchers who are part of a company spun out from Hasbro Inc. to provide interactive aid and comfort for older adults.

The project, dubbed ARIES (Affordable Robotic Intelligence for Elderly Support), is adding artificial intelligence capabilities to the Joy for All Companion Pets from Ageless Innovation, a former Hasbro group. The team, which also includes researchers from Butler Hospital and the University of Cincinnati, is developing additional capabilities for animatronic companions to help with tasks that could include finding of lost objects and reminding about medication.

“This project really represents what we do at HCRI, which is to let societal needs drive technology development,” said Bertram Malle, a professor of cognitive, linguistic, and psychological sciences at Brown, codirector of HCRI, and principal investigator on the grant.

The ARIES team is evaluating challenges older adults face and testing technical approaches to equip robotic companions. “The Joy for All Companion Pets make some realistic pet sounds and gestures,” Malle said. “We may want to expand those capacities and add intelligence, so the companions give meaningful clues—gestures, nudges, purrs—that help guide users toward misplaced objects or let them know it’s time to do something.”

Michael Littman, a professor of computer science at Brown and coprincipal investigator, said, “The ‘A’ in ARIES stands for affordable. This is one of the important reasons Ageless Innovation is a great industry partner for this project. The current Joy for All Pets cost roughly $100, while similar robotic products can cost $5,000 to $6,000. We want the ARIES robot to be available to anyone who needs it.”

Artificial intelligence will make robotic cats and dogs more useful as companions.

Health Decoders

Biomedical Informatics center is broadening opportunities by making data accessible.

“We’re going to meet an incredibly large research need across the state.”
—Neil Sarkar

Even in a state as compact as Rhode Island, researchers have long had a hard time accessing the statewide health data essential to their projects.

With the Brown Center for Biomedical Informatics creating new opportunities at Brown and throughout the state, that’s now changing. Three years since the center’s founding, it has sparked a wide range of research projects aimed at studying preterm births, opioid use disorder, suicide risk, and more.

“We have really changed the landscape as to how biomedical researchers are able to get access to data and continue working with that data within a secure environment,” said Director Neil Sarkar.

For Megan Ranney, an associate professor of emergency medicine at the Warren Alpert Medical School and director of the school’s Emergency Digital Health Innovation program, the center is helping to generate new data sets on opioid use from the Lifespan hospital system. It will allow her to model opioid use, predicting which patients are at high risk for abuse, and identify patients at risk of return emergency visits. The center is building data sets for many other researchers and topics, including one intended to help predict suicide risk and another to devise new ways to help kids with asthma.

Associate Director Elizabeth Chen said the center has made significant progress in solving the challenge of finding secure places to store and analyze data so they are accessible to researchers and also protects patient privacy.

Sarkar said, “I’m expecting that in the next year or two, as more and more researchers work with us, we’re going to meet an incredibly large research need across our state. We’re starting to enable clinicians of tomorrow to use data to provide better quality care in a more efficient way.”

The center is a component of Advance-CTR, a statewide partnership based at Brown and funded by the National Institutes of Health. It provides funding and other resources to clinical and translational researchers across Rhode Island. **—Elena Renken ’19**

Neil Sarkar (left) and Elizabeth Chen.

CHRISTOPHER BRAND; BROWN UNIVERSITY

The Case for Mindfulness

Rigor is used to ensure claims are backed by science.

As health interventions based on mindfulness have grown in popularity, so has concern that the evidence base for such practices is not yet robust enough. A new Brown study shows how a rigorous approach can help ensure that claims are backed by science.

Mindfulness-based interventions sometimes blend practices, which makes it difficult to measure how each practice affects participants, said lead author Willoughby Britton, an assistant professor of psychiatry and human behavior at the Warren Alpert Medical School.

Researchers took a common intervention for mood disorders—mindfulness-based cognitive therapy—and created a study isolating its two main ingredients. Those are open-monitoring (OM)—noticing negative feelings without judgment or an emotional secondary reaction; and focused-attention (FA)—maintaining focus on or shifting it toward a neutral sensation, such as breathing, to disengage from negative emotions or distractions.

"It has long been hypothesized that focused-attention practice improves attentional control, while open-monitoring promotes emotional non-reactivity," said Britton. "However, because these two practices are almost always delivered in combination, it is difficult to assess."

More than 100 individuals with mild to severe depression, anxiety, and stress were enrolled in eight-week courses. The FA-only group reported much greater improvement in the ability to willfully shift or focus attention than the OM-only group. Meanwhile, the OM-only group was significantly more improved in being non-reactive to negative thoughts.

"End users can alter the amount of each practice to fit their individual needs," Britton said. "The study created validated single-practice programs that can be used by other researchers or providers. This is the first step to an evidence-based personalized-medicine approach to mindfulness."

Britton conducted the study, published in *Behaviour Research and Therapy*, with Eric Loucks, an associate professor of epidemiology and medicine who directs Brown's Mindfulness Center; and Jared Lindahl, who teaches contemplative studies at Brown. The National Institutes of Health, the Mind and Life Institute, and Brown's Contemplative Studies Initiative funded the research.

The Mindfulness Center, launched in 2017 and continuing to expand, includes a range of grant-supported research, as well as education and community programs. It is housed in the Brown School of Public Health and also associated with members of the Warren Alpert Medical School and the Contemplative Studies Initiative.

KAREN PHILIPPI

Innovating with Industry

Growing efforts include Innovation Hub in Providence and a new biomedical fund.

In 2016, Rhode Island voters approved a $20 million bond issue to create Innovation Campuses to stimulate the translation of academic research into new commercial partnerships, products, and jobs.

Teaming up with organizations around the world, universities around the state submitted proposals, and Brown won an award to develop an Innovation Hub (iHub) in Providence.

The state awarded $2.5 million to Brown and its iHub partners, the University of Rhode Island, IBM Alpha Zone, and MassChallenge, in December 2018. The 5,000-square-foot iHub will be in Providence's Jewelry District. It expects to be a magnet for start-ups; spark interactions between entrepreneurs, industry, academic researchers, and students; incubate emerging companies; and offer educational programs.

"Having iHub enables the critical 'innovation density,' a key ingredient to catalyzing the area's innovation economy," said Daniel Behr, executive director of Brown's Office of Industry Engagement and Commercial Venturing (IECV). "It is an example of our efforts to innovate by engaging with the commercial ecosystem in order to unleash the impact of Brown's research."

Also, as part of the University's enhanced commitment to spawning innovation, Brown Biomedical Innovations to Impact (BBII) is expanding. Created by Jack Elias, senior vice president for health affairs and dean of medicine and biological sciences at Brown, and comanaged by IECV, BBII funds the transformation of early-stage biomedical innovations into commercial opportunities—thus bridging the gap between the time when research funding sources like the National Institutes of Health are discontinued, and industry and investors become willing to step up. BBII, supported by gifts totaling more than $8 million, recruited its first managing director, Karen Bulock, and expects to fund major projects in 2019.

The Innovation Hub and BBII are part of *Brown and the Innovation Economy*, a plan to maximize Brown's impact on innovation, entrepreneurship, and job growth that was developed by a team that Provost Richard M. Locke led. Locke said, "As we strengthen academic excellence at Brown and address pressing real-world issues through teaching, research, and public engagement, this initiative bolsters Brown's connections with public, private, and nonprofit partners and helps focus our resources toward economic growth and job creation."

—Noel Rubinton '77

DAVID DELPOIO; SUSAN JOHANN

Research is being used to boost entrepreneurship and job growth.

ALUMNI IMPACT

LYNN NOTTAGE '86, THE ONLY WOMAN TO HAVE WON THE PULITZER PRIZE FOR DRAMA TWICE, IN 2009 AND 2017, SAID SHE WAS INSPIRED BY AFRICANA STUDIES' RITES AND REASON THEATRE AT BROWN.

"I certainly use the skills that I learned, building upon ancestral texts to really access my own personal narrative and figuring out a way we could become part of that continuum. I'm very interested in excavating the stories of people who have been marginalized. I learned how to celebrate my own story and tell it in a way that is rooted in tradition that goes back to Africa."

What Babies Can Do

Infants are found to have surprising capacity to learn, remember, and find context.

An infant looks at a screen, where a series of shapes was presented.

COURTESY KRISTEN TUMMELTSHAMMER; DR. HOWARD AND MOGULDOM; FACING PAGE, DE AGOSTINI/G. DAGLI ORTI/AGE FOTOSTOCK AMERICA

Just six months into the world, babies already have the capacity to learn, remember, and use contextual cues to guide them searching for objects of interest, such as faces.

That was the central finding of a study by Dima Amso, an associate professor in Brown's Department of Cognitive, Linguistic, and Psychological Sciences, and Kristen Tummeltshammer, a postdoctoral scholar.

"It was pretty surprising to find that 6-month-olds were capable of this memory-guided attention," said Tummeltshammer, the lead author of the paper published in *Developmental Science*.

Amso said learning that infants can recognize and exploit patterns of context provides important new insights into typical and possibly atypical brain development.

"They are efficient in using the structure in their environment to maximize attentional resources and to reduce uncertainty and distraction," Amso said. "A critical question in our lab has been whether infants at risk for neurodevelopmental disorders, especially autism spectrum disorders, have differences in the way they process visual information, and whether this would impact future learning and attention."

In the research funded by the James S. McDonnell Foundation and the National Institutes of Health, Tummeltshammer and Amso invited the parents of 46 healthy, full-term infants, either 6 or 10 months old, to bring their children to the lab to play a game of finding faces. Seated on a parent's lap, the babies simply had to watch a screen as they were presented with a series of arrangements of four colored shapes. The shapes would turn around with one revealing a face. An eye-tracking system would measure where the baby looked.

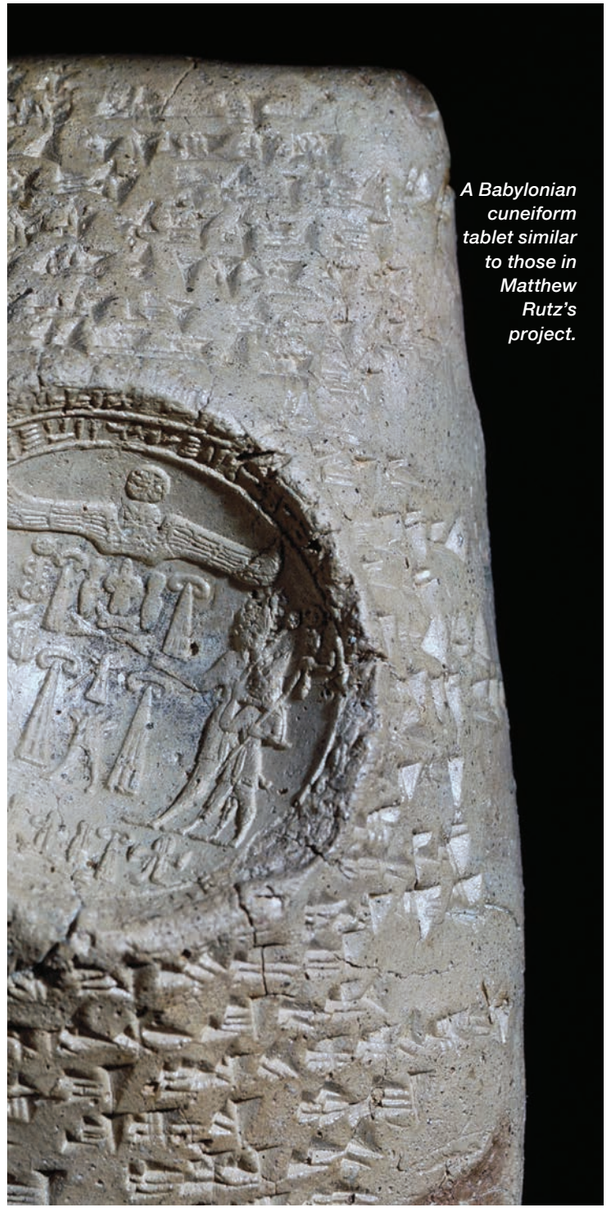
There was little difference between the 6-month-olds and the 10-month-olds, Tummeltshammer said, suggesting the skill is developed at the younger age.

"We think of babies as being quite reactive in how they spread their attention," she said. "This helps us recognize they are actually quite proactive.

ALUMNI IMPACT

AYANNA HOWARD '93, RECENTLY NAMED CHAIR OF THE SCHOOL OF INTERACTIVE COMPUTING AT GEORGIA TECH, GOT HER START IN ROBOTICS WHILE STUDYING ENGINEERING AT BROWN.

"I'd been wanting to do robotics forever, and this was the first time I touched real hardware. I was working on how you use robots to basically grab an object without pushing it or breaking it. It inspired me to think about manipulation. Research is key for getting students to continue because it actually allows them to see how to apply the theory they're learning in the classroom to real-world problems."



A Babylonian cuneiform tablet similar to those in Matthew Rutz's project.

On the Horizon

Three early-stage projects are showing promise.

PRESERVING TABLETS IN SYRIA

The National Endowment for the Humanities has awarded Matthew Rutz, associate professor of Egyptology and Assyriology at Brown, a $166,632 grant to digitally preserve culturally significant clay tablets in Syria.

The project, codirected by Jacob Lauinger of Johns Hopkins University, will enable researchers to explore the country's ancient history and provide new tools for understanding writing on the tablets. The digital preservation project will bring into a searchable database the text of thousands of clay tablets inscribed in cuneiform script. The tablets document the political, social, and economic life of Ugarit, a cosmopolitan city that flourished more than 3,000 years ago.

Rutz and Lauinger will translate from Ugarit into English 1,887 cuneiform texts in a single online resource, enhancing scholarly and public access to the texts. "These are ancient, historically unique documents that are imperiled by modern-day conflict in Syria," Rutz said.

AFRICAN AMERICANS WITH HIV

Chanelle Howe and Akilah Dulin, assistant professors in Brown's School of Public Health, are leading a five-year, NIH-funded, multi-institution study examining the role of "resilience" among African Americans living with HIV.

"Resilience is about thriving despite adversity," said Howe. After the team develops a new resilience measure, they will use it to determine whether resilience is associated with outcomes such as adhering to HIV medications. If resilience can be shown as a significant contributor to better HIV outcomes, researchers hope to design ways to increase it among persons living with HIV, and reduce persistent HIV racial disparities.

"The goal is to increase the proportion of people living with HIV with a suppressed HIV viral load, especially among African Americans," Dulin said.

TRAINING BROWN SCIENTISTS

Brown and the U.S. National Institute of Standards and Technology (NIST) have started a five-year partnership that will enable Brown scientists to work in NIST laboratories as they advance research and develop new discoveries.

NIST, one of the nation's leading physical science laboratories, will provide funding to cover living expenses and other needs while Brown researchers work at NIST locations in Gaithersburg, Maryland, and Boulder, Colorado, with potential aid totaling more than $13 million.

The program is open to any Brown researcher working in physical sciences. NIST develops measurement standards used in everything from nanoscale devices and microchips to skyscrapers and global communications networks.

"This is a fantastic opportunity for faculty and students at Brown to collaborate with some of the best researchers in the world at some of the world's most advanced facilities," said Larry Larson, dean of Brown's School of Engineering. "For NIST, it's an opportunity to tap into the expertise of the faculty here as well as help to train—and potentially hire—some of our exceptionally talented grad students and postdocs."

ALUMNI IMPACT

DAVID DE LUCA ’85, WHO RECENTLY BECAME HEAD OF GLOBAL EQUITIES AT RAYMOND JAMES FINANCIAL INC., CONCENTRATED IN POLITICAL SCIENCE AT BROWN.

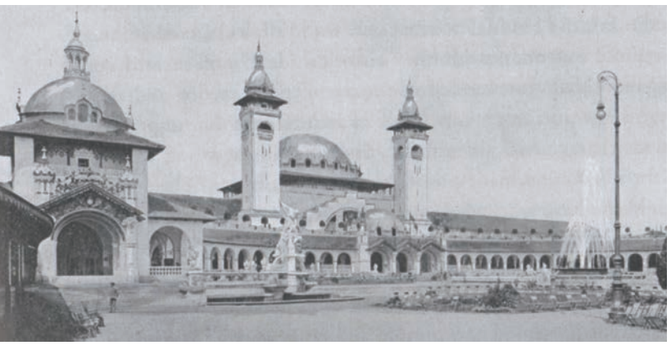
“My research as part of my undergraduate honors thesis—which delved into Congressional oversight of covert military action—ignited a lifelong interest in academic research, culminating in two graduate degrees, including one in international relations. The research skills I attained at Brown have served me in my career and nourished my personal interests.”

Reconstructing Architecture

Sifting through visual language in the built environment can decode messages and ideas.

Itohan Osayimwese is an architectural historian at Brown, but she works much like an archaeologist, sifting through visual language to see how it is translated into messages and ideas.

Osayimwese believes that many people still don’t think of Germany as a colonial power of the 19th century and do not understand the country’s modern architectural history in relation to larger developments worldwide. When Osayimwese, an assistant professor of history of art and architecture, did the research for what became the book *Colonialism and Modern Architecture in Germany*, she aimed at widening the conceptual and geographic lens of architectural history.



Main hall of Berlin Trade Exhibition, 1896.

RAYMOND JAMES; UNIVERSITY OF PITTSBURGH PRESS

Her book, which became the first major English-language study of the subject, encourages people to form links between Germany’s modernist architecture and its colonial venture. It associates the “economic challenges of Germany’s colonial project” with what Osayimwese said was the abandonment of a “centuries-long, highly ornamental architectural style in favor of an architectural language based on structural technologies and building materials.” She said her analysis took advantage of architecture’s ability to reflect a society’s ideologies, technological advancements, economic situation, and social and political concerns.

Osayimwese’s book earned a Society of Architectural Historians/Mellon Author award, and she is the winner of a 2017 Brown Early Career Research Achievement award. Osayimwese’s current research includes studying the historical effects of migration on the built environment on the Caribbean island state of Barbados from emancipation to the 20th century, and gender and the modernist artistic avant-garde in postcolonial Nigeria.

—Liyaan Maskati ’21

Research Honors

Six professors receive Brown achievement awards.

In recognition of outstanding work across a wide range of academic areas, Brown’s annual Research Achievement Awards were given to six faculty members in April 2018.

“These awards are the University’s recognition of the research contributions of some of our extraordinary faculty,” said Jill Pipher, vice president for research and professor of mathematics. “Each of these individual award winners has transformed research fields through deep scholarship and creative solutions to complex problems.”

Nominations for the award were sought in six categories and reviewed by panels of Brown faculty. Besides the award, each winner received a $5,000 research stipend.

“Research is central to Brown’s mission,” Provost Richard M. Locke said at the awards ceremony. “It’s crucial to innovation and discovery and essential for advancing just, peaceful, and prosperous societies locally and globally. Research is also vital to our quest to educate highly capable leaders across the disciplines, and we celebrate these award winners for their commitment to excellence, exceptional collaboration, and mentoring of the next generation of scholars.”

Winners of the 2018 Distinguished Research Achievement Awards are:

- **Huajian Gao** (*engineering*), for lasting contributions in his primary field, the mechanics of solids and structures, such as in the mechanics of thin films and nanostructured and energy storage materials.
- **Rose McDermott** (*international relations*), for her pioneering scholarship, including in the area of political psychology, and her innovative interdisciplinary work, which includes political science, international relations, psychology, and behavior genetics.
- **Rena Wing** (*psychiatry and human behavior*), cited as one of the top researchers for the treatment of obesity and related health problems, especially Type 2 diabetes.

Winners of the 2018 Early Career Research Achievement Awards are:

- **Erica Larschan** (*molecular biology, cell biology, and biochemistry*), for the strong start in her career in terms of both basic research and medical applications, including important discoveries in the field of gene regulation involving the CLAMP protein.
- **Itohan Osayimwese** (*history of art and architecture*), for her research in the fields of modern architecture and colonial studies, looking at intersections between geopolitics and architectural discourse.
- **Stefanie Tellex** (*computer science*), for her artificial intelligence research as she designs new approaches for humans to communicate with robots that could revolutionize such interactions.

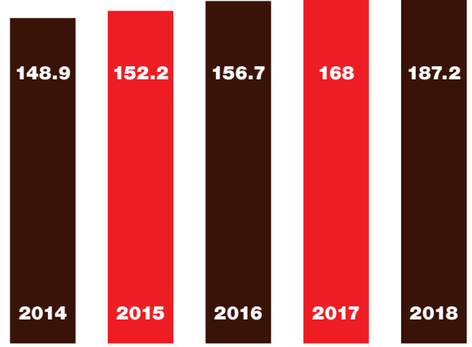
VICTOR ALVAREZ ’19

PERFORMANCE AND BEYOND: ***In its second year, the Brown Arts Initiative (BAI), which includes six academic departments and two programs, expanded its research, teaching, and performance activities. Here, artist Kelly Nipper (right) talks with RoseLee Goldberg, founder of Performa, which promotes visual art performance and is a BAI institutional partner.***

Nipper’s new work, Terre Mécanique, was developed on site at Brown’s Granoff Center with the assistance of Brown students and designers from MIT’s Self-Assembly Lab. Encompassing dance, photography, scientific inquiry, and performance, it then premiered in New York City with Brown students attending.

Rising Funds

Brown’s research expenditures in millions of dollars, fiscal years 2014 to 2018



Source: Brown University Research Administration Information Systems & Reporting

Using History

A gift of remarkable Jewish Passover books becomes a rich resource.

When Steven Ungerleider approached Brown about donating rare Jewish books he had collected—Passover Seder texts that go back hundreds of years, from around the world—a key question arose: Would the books be a valuable resource for the University?

The answer that came back was a resounding yes, it would spark much new scholarship. The Dr. Steven Ungerleider Collection of Haggadot was created in 2018, taking its place alongside other special library collections.

"This collection presents exceptional teaching and research opportunities across disciplines," said President Christina Paxson. "The impact it will have on scholarship for faculty and students is profound."

Ungerleider, a psychologist and Olympic sports medicine specialist, gave the books in honor of his father, Samuel Ungerleider Jr. '39. Available in person at the John Hay Library, many of the books also have been digitized to provide worldwide access. The collection already has been the subject of a public exhibition and a symposium with scholars from around the country.

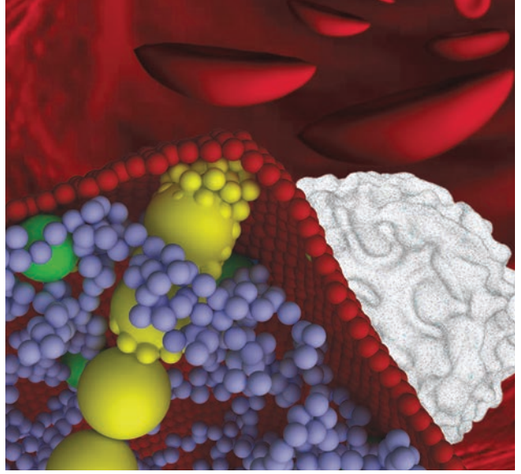
More than 400 volumes go back over 500 years, coming from Jewish communities in the Americas, Asia, Africa, Europe, and the Near East.

"It would be hard to overstate the importance of the collection for anyone interested in the history of Jewish culture, the Jewish religion, and the Jewish people," said Adam Teller, professor of Judaic studies and history.

Beyond Judaic studies, Teller said the collection is expected to attract research in religious studies, history, the history of art, music, and other fields. **—Noel Rubinton '77**

A 1887 Haggadah (left) published in New York was one of the first to reflect the American Jewish experience; it included a new view of the "Four Sons" story. A Haggadah published in London in 1806 (right) had fold-out maps of key sites.

DR. STEVEN UNGERLEIDER COLLECTION OF HAGGADOT; ERIK GOULD (2)



Computer models enable researchers to see what happens inside red blood cells.

Calculating Sickle Cell

Mathematics is being used to understand and combat disease.

Disease fighters are commonly pictured as doctors or other scientists with their eyes pressed to microscopes. But Brown applied mathematics professor George Karniadakis is taking another path to combat sickle cell disease: using computer models to visualize how it transforms red blood cells.

With his team, Karniadakis is developing modeling tools to assess potential drugs for treating sickle cell disease. Only two approved drugs exist currently, but there are many in development that harness different mechanisms to combat the disease. Assessing which will be most effective may be key to finding a way to aid sickle cell patients and reduce disease symptoms.

Karniadakis's lab simulates how hemoglobin forms fibers that force red blood cells out of their soft, round state. These models work on multiple scales, processing molecular changes only where a fiber is growing, while the rest of the fiber is modelled in much lower resolution. Only with this approach have computers been able to simulate the mechanism of sickle cell disease in so much detail—otherwise there's been far too much data to handle. His work to provide new understanding of the disease was published in *Biophysical Journal*.

Using mathematics to understand and combat diseases is a growing field, Karniadakis said. "It's not just the genes and proteins—it's also the mechanics of it. We can characterize the disease, and the severity of the disease, by how soft the cells are, by how stiff they are, by their shape.""

Karniadakis collaborates with fellow scientists to gather clinical and experimental data that show how red blood cells move through the body and change internally. This information informs his models, which generate more accurate depictions of these complicated cells than was previously possible. "Now we're in a position where we actually include all this complexity and functionality," Karniadakis said. **—Elena Renken '19**

KARNIADAKIS LAB/BROWN UNIVERSITY

From Concept to Clinic

$50M gift will enable discoveries to move from medical labs toward market.

Translating biomedical research and discovery into treatment and cures for disease is a top goal of Brown's Warren Alpert Medical School, and a new $50 million gift is propelling those efforts.

The gift, from Brown Chancellor Samuel M. Mencoff '78 and his wife, Ann S. Mencoff, is supporting the Brown Institute for Translational Science (BITS), part of the Warren Alpert Medical School. Half of the gift will be dedicated to establishing endowed faculty chairs and funding outstanding researchers, with the remaining $25 million supporting other medical education and research.

"Over recent years, major investments in research in areas like immunology, cell biology, and genetics have provided impressive insights into the basic biology of fundamental processes," said Jack A. Elias, dean of medicine and biological sciences and senior vice president for health affairs. He said investments like the February 2018 Mencoff family gift are essential because they allow faculty to focus on the next step, converting scientific discoveries into medical breakthroughs tested in the clinic and brought to patients.

Philanthropic investments give researchers the agility to pursue new studies or alter the design of studies in response to new data without the lengthy processes required to pursue federal or foundation grants. "These investments keep Brown on an ambitious trajectory for moving research out of the labs and into clinics in areas like respiratory diseases, aging, Alzheimer's disease, and malaria," Elias said.

This excites Jonathan Kurtis '89, '95 PhD, '96 MD, chair of pathology and laboratory medicine, and director of the medical school's MD/PhD program. Kurtis has developed a promising malaria vaccine poised to begin human trials in Africa. He has been awarded numerous grants, yet said obtaining funding for fighting diseases in developing countries can be challenging.

The Mencoffs' gift has already facilitated recruitment of two leading researchers. Jeffrey Bailey, who studies the role of genetic variation in immunity and disease, particularly malaria, joined the pathology department in October 2018. Wafik El-Deiry became inaugural associate dean for Oncologic Sciences, overseeing a new joint program in cancer biology for Brown and the Lifespan health system.

Daphne Koinis-Mitchell (left) and Beth McQuaid are building an NIH-funded pediatric asthma center.

KAREN PHILIPPI

Controlling Asthma

Integrated program focuses on low-income children, families

For more than two decades, Brown researchers have honed approaches to preventing and reducing asthma symptoms among Rhode Island children. Now, with an $8 million grant from the National Heart, Lung, and Blood Institute, they are expanding programs to reach 1,500 children and families, with hopes to create a national model.

Project leaders Elizabeth McQuaid and Daphne Koinis-Mitchell, Brown professors of pediatrics and psychiatry and human behavior, have developed programs that improve asthma outcomes, including better control of symptoms, fewer emergency department visits, lower incidence of complications like allergies and poor sleep, and fewer missed school days.

McQuaid and Koinis-Mitchell have built on prior initiatives' success in establishing the Rhode Island Asthma Integrated Response Program (RI-AIR). Seed funding from the Brown-based Hassenfeld Child Health Innovation Institute gave them important access to mapping and informatics expertise.

"We're not testing whether these interventions work," McQuaid said. "We know they work."

Instead, to reach as many children as possible, they're evaluating potential barriers, sustainability, and cost effectiveness.

Asthma is more prevalent in cities than other areas and is exacerbated in low-income housing, which is more likely to harbor triggers like mold and pests, the researchers said. Beyond health impacts on those in low-income housing, where a disproportionately high number of African American and Latino children live, asthma is linked to lower educational achievement, physical activity, and social engagement.

"It's not just about asthma," Koinis-Mitchell said. "It's about all the other outcomes."

RI-AIR aims to better control asthma through either school- or home-based care in 16 communities in Providence, Pawtucket, and Central Falls that have high rates of pediatric asthma and emergency department use.

The ultimate goal of the grant is to find effective models that can be shared with the rest of the country. That opportunity—to help not just thousands but millions of kids struggling with asthma—is validation for the researchers. "All the work we have done," McQuaid said, "has in many ways been building toward this." **—Phoebe Hall**

CONFRONTING OPIOIDS

Leading Brown researchers help reduce Rhode Island deaths and suggest new national directions.

BY MAURA SULLIVAN HILL

Jody Rich recalls sitting in the Rhode Island Medical Examiner's office in Providence, a two-foot high stack of folders piled on the table in front of him.

The files contained a large part of the story of the opioid epidemic in Rhode Island: autopsies and toxicology reports, police reports and witness statements, medical records and death scene photographs.

"This whole time you're reading through this folder … you know how it's going to end: it's tragic," said Rich, professor of medicine and epidemiology at Brown. "It's the death scene photographs—you can't unsee those. One image was a woman who was pregnant and had a baby shower earlier in the day, and in the photo she is just slumped among all the presents she had just received. It weighs on you, the magnitude of this epidemic and tragedy."

In the four years before Rhode Island Gov. Gina Raimondo took office in 2015, opioid deaths in the state nearly doubled. One of her first moves in office was to create a task force to confront the opioid epidemic, and she tapped three experts from

COURTESY TRACI GREEN; GLENN OSMUNDSON

Traci Green (left), Jody Rich (center), and Brandon Marshall are developing new strategies to reduce opioid overdoses.

Brown—Rich; Brandon Marshall, an associate professor of epidemiology at Brown's School of Public Health; and Traci Green, an adjunct associate professor of emergency medicine and epidemiology—to help lead the way.

"As expert advisors, we had 90 days to come up with an actionable plan to confront the crisis," Rich said. "So we scrambled. And Traci, she's brilliant. She said, 'We have to find out why people are dying. We have to go to the medical examiner's office.'"

Green's instincts were correct, and their hours spent combing through files yielded important answers—prominently, that heroin laced with fentanyl, a highly potent opioid, was often the cause of these overdose deaths. This insight led to action, including a groundbreaking program of addiction treatment for prisoners in the state.

In Rhode Island, overdose deaths increased by nearly 90 percent between 2011 and 2017, with 250 to 300 people dying annually. In 2017, more than 70,000 Americans died from overdoses, according to the Centers for Disease Control and Prevention, and the U.S. Department of Health and Human Services officially declared the opioid crisis a public health emergency.

REASONS FOR HOPE

"Research into opioid use and treatment is an urgent national priority. Against this bleak picture of a national opioid crisis, though, Rhode Island and Brown University have offered reasons for hope," said Brown University President Christina Paxson, speaking at an October 2018 "Frontlines of the Opioid Crisis: Innovative Science-Based Solutions" event at Brown cosponsored by the American Academy of Arts and Sciences.

"In 2017, opioid-related deaths have dropped … in Rhode Island, the first significant decline in almost a decade. And the state and Brown continues to be widely recognized for generating innovative research and treatment plans that are helping to ease the crisis, and which could provide models for the rest of the country," Paxson said.

Efforts to combat drug use in the United States have long focused on incarceration and criminal justice deterrents. However, Rich, Green, and Marshall all found through their research that criminal justice efforts are not the most effective ways to deter or rehabilitate people who use drugs. Much of their work offers an alternative focused on expanding treatment and rehabilitation options, and reducing the stigma around opioid addiction.

Addiction treatment for Rhode Island prison inmates has reduced overdose deaths.

"Instead of bringing people into the criminal justice system, we need to bring them into treatment," Rich said. "Individuals don't die of opioid overdoses because we didn't have enough arrests, incarceration, or police presence. They die because we have too much of that and not enough treatment."

Rich is the director of the Center for Prisoner Health and Human Rights at the Miriam Hospital in Providence, and he has been treating prison inmates for the past 25 years. In 2018, he was elected to the National Academy of Medicine—regarded as one of the highest honors in the fields of health and medicine—for contributions that include his work on opioids.

His usual routine of biking on Tuesday mornings to the prison where he works has remained unchanged over those years, but in 2016, his research led treatment plans to change dramatically. He and Green helped Jennifer Clark, medical director at the Rhode Island Department of Corrections and a fellow faculty member at Brown's Warren Alpert Medical School, as Clark launched a new treatment program that is still the only one of its kind in the United States.

It treats inmates, using medication for addiction treatment—drugs like methadone, buprenorphine, and naltrexone—which helps wean them off drugs and reduces risk of overdose upon release. Other programs use one of these drugs, but Rhode Island's is the only one to offer all three options. In the first year of this program, post-incarceration overdose deaths decreased by 61 percent, contributing to a statewide 12 percent drop in overdose deaths. The team published its findings in a *JAMA Psychiatry* study in February 2018 that attracted wide attention.

Research by Rich and others has shown that treating people with effective medications—rather than them stopping "cold turkey"—is more successful in fighting opioid addiction. Inmates are at higher risk of overdose when they are released if they don't receive treatment while imprisoned.

"They may have stopped using because they are incarcerated, but nothing has been done to change the pathways in the brain responsible for addiction," Rich said.

NEW CENTER OF EXCELLENCE

Rich is also the principal investigator of the new Center of Biomedical Research Excellence on Opioids and Overdose at Rhode Island Hospital, created in 2018 with an $11.8 million federal grant. Green is codirector of the center, and Marshall is a core director. Their work will focus on understanding more about the causes of opioid addiction, as well as exploring further treatment methods.

Marshall brings another dimension to opioid efforts, focusing on harm reduction strategies because, he said, "Not everyone is ready for treatment. We need to keep people alive long enough to be willing to accept treatment. I see harm reduction programs as working arm in arm with addiction treatment strategies."

ADULT CORRECTIONAL INSTITUTION

NaloxBox (above) designed by Brown and RISD professors, is on a wall for use if needed at Amos House, a Providence social service facility. Research shows rapid-acting fentanyl test strips (right) help reduce overdose risk.

NICK DENTAMARO (2)

After conducting a study with rapid-acting fentanyl test strips in 2017, he found test strips have the potential to make a big impact. In the year prior to the study, 56 percent of drug deaths in Rhode Island occurred because of fentanyl-laced drugs, primarily heroin. The strips work like an over-the-counter pregnancy test to warn drug users of the presence of fentanyl.

Marshall and his research team provided test strips to drug users and found that they not only used the strips, but often changed their behavior to reduce overdose risk. "The work we've done has shown that most people who use illicit drugs or opioids would very much like to avoid fentanyl," Marshall said.

"INSTEAD OF BRINGING PEOPLE INTO THE CRIMINAL JUSTICE SYSTEM, WE NEED TO BRING THEM INTO TREATMENT."

—Jody Rich

Marshall's study, published in the *International Journal of Drug Policy* in October 2018, showed that fentanyl test strips could help reduce overdoses. He is now expanding the study to a bigger sample size.

He is also using a new $800,000 grant from the Laura and John Arnold Foundation to study the influence of peer recovery support specialists, who have been through their own addiction and recovery, and work at emergency departments throughout Rhode Island with patients who have overdosed.

In addition, Marshall is the scientific director of PreventOverdoseRI.org, the information dashboard and online presence for the state's drug overdose task force. Using infographics, interactive maps, charts, and videos, the site provides resources for individuals at risk or their friends and family members. Epidemiological data are updated regularly by Marshall and his team of undergraduate and graduate researchers at the Brown School of Public Health.

"By understanding where overdoses are occurring and who is most affected, we can develop programs that more effectively respond to the needs of communities across Rhode Island," Marshall said.

On another front, along with colleagues at Rhode Island Hospital, Boston University, and the University of Rhode Island College of Pharmacy, Green is leading a study to understand how to boost access to naloxone, a medication to counter overdoses, through pharmacies.

CVS Pharmacy, headquartered in Woonsocket, R.I., and several independent pharmacies are collaborators, and have substantially increased their naloxone disbursement as a result of the study.

Green said a separate study is training and equipping Rhode Island pharmacies to provide medication treatment for addiction care.

"In crisis comes opportunity," said Green. "The pharmacy could be a new partner to provide better, patient-centered care for opioid-use disorder, like we have seen in the prison and jail. We think this could be a game-changer for addiction care."

Other opioids efforts continue to broaden at Brown. The Association of American Medical Colleges gave the Warren Alpert Medical School a 2018 curricular innovation award for how it advanced the education and training of students, residents, and practicing physicians about opioids.

While overdoses are decreasing in Rhode Island, Rich, Green, and Marshall say there is a long road ahead. Next, they want to share more of their research and data-driven policy advising with other states and address the crisis nationwide. Green said that, because Rhode Island is a small state, the statewide efforts here can be applied at the county level in larger states.

"This is the service part of academic work," Green said that because Rhode Island is small, statewide efforts can be applied at the county level in larger states., the only constant was that the deaths were going up. But the community came together and we were very strategic and intentional about evidence-based decision making. The data, the deaths, and the patterns showed us a way forward."

EUREKA MOMENTS

In the expanding Carney Institute for Brain Science, discoveries are powering progress.

BY NOEL RUBINTON ’77

COURTESY BARNEA LAB

With trans-Tango technology developed at Brown, scientists can see connections between neurons and trace brain circuits.

GILAD BARNEA remembers his "Eureka" moment. After 20 years of work on his "trans-Tango" project, he was sitting in his Sidney Frank Hall office at Brown when a student in his lab rushed in with a picture that showed it was finally working.

Considerably more work remained before the discovery would be formally announced with publication in the journal *Neuron* in the fall of 2017, but the goal was in sight.

After years of efforts aimed at finding a powerful new way of studying neural circuits, "that was an amazing moment," recalled Barnea, an associate professor of neuroscience. The new technology reveals which neurons are connected with others and makes it possible to trace brain circuits, which is key information in understanding and treating disease. It is recognized as a tool that could lead to many more discoveries, both in techniques and therapies. "Our system endows you with genetic accessibility to neural circuits based on connectivity," Barnea said.

Now that the basic technique is proven, work with trans-Tango is expanding. After years of research using fruit flies, it is now being tried with mice, zebrafish, and chicks. And new versions of the technique are being tested to study cancer and also the immune system. In each new use, it will need to be "tweaked" to operate correctly, yet Barnea is confident that trans-Tango "is bound to give us insights into disorders of the nervous system."

Many researchers might have given up years earlier, Barnea said, but he kept going with his "obsession," first as a postdoc at Columbia University and then coming to Brown halfway into his two decades of work.

Gilad Barnea surveys shelves full of research flies in his lab.

"Brown was perfect for this," Barnea said, as the University provided the needed intellectual environment and crucial internal funding at key points prior to getting a succession of external grants. He said Brown has been the source of "spectacular undergraduates" for his lab (five of whom were listed as authors on the key published paper), along with graduate students, postdocs, and supportive faculty colleagues.

PERSISTENCE LIKE BARNEA'S is not unusual in brain science. The study of the brain and its relationship to cognition, behavior, and disease is often described as the "last frontier" in biomedical science, and many of its vital questions have remained extremely difficult to answer.

In 2018, Brown received one of the largest gifts in its history to support brain science research. Aiming to quicken the pace of scientific discovery about the brain and find cures to some of the world's most persistent and devastating diseases, such as ALS and Alzheimer's, Robert J. Carney '61 and Nancy D. Carney gave Brown $100 million for the brain science institute, and it was renamed in their honor.

"This is a signal moment when scientists around the world are poised to solve some of the most important puzzles of the human brain," said Brown President Christina Paxson. "This extraordinarily generous gift will give Brown the resources to be at the forefront of this drive for new knowledge and therapies. We know that discoveries in brain science in the years to come will dramatically reshape human capabilities, and Brown will be a leader in this critical endeavor."

Diane Lipscombe, director of the Carney Institute and a professor of neuroscience, called the Carneys' gift "lifeblood to driving innovation and discovery." It will be used to accelerate hiring of leading faculty, supply seed funding for high-impact new research, and fund essential new equipment and infrastructure in technology-intensive areas of exploration.

JUDY LIU IS THE KIND OF RESEARCHER that the Carney Institute plans to build its growth around.

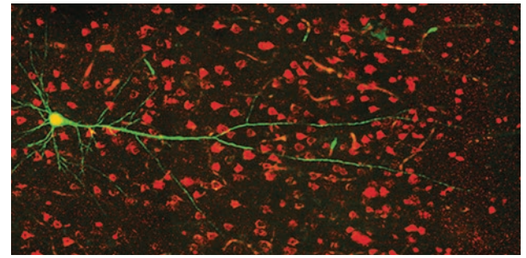
A physician-scientist looking for an epilepsy cure, she had a plan. Liu thought examining patient samples would hold the key to understanding severe epilepsy. In fact, her team had identified a change in the CLOCK protein in brain tissue that generates seizures.

The next step was to develop an animal model to study the effect of decreased CLOCK on seizures. When she was examining the data for the mice engineered for this purpose, she had mountains of information. Trying to streamline her analysis, she focused on the mice during their waking hours and saw no evidence of seizures or a connection with epilepsy.

Then she had an aha moment, realizing she had to look at the complete sleep-wake cycle. When she examined the sleep periods of mice, she said, "It was so unbelievable." In sleep, the link between lack of CLOCK and seizures suddenly became vivid. It was a turning point in her research, and her findings have given hope for a new way to develop treatment for some of the most severe cases of the disabling disorder.

"If we start worrying about how long it will take, we'll never get started," Liu said. "Neuroscience and particularly neurological disease have eluded biomedical researchers in finding cures." While it won't be easy or quick, Liu said she's hopeful that progress can be made on epilepsy because of the insight about CLOCK. She said a strategy for further research could be to deliver a drug that compensates for the lack of CLOCK, directly in a specific part of a patient's brain.

Liu conducted four years of research on the CLOCK protein while at the Children's National Medical Center in Washington, D.C., and, shortly before it was published in *Neuron* in October 2017, she came to Brown as an assistant professor of neurology. Liu said she wanted to be at Brown and the Warren Alpert Medical School because of "the amazing basic science community," and already she's advancing her work in many new directions. The ability to collaborate at Brown has been fruitful right away, as she has seen that lab space and researchers are not in silos. "Having world experts in neuroscience around me will make things go faster," she said.



In defining the role of CLOCK protein deficiency, Judy Liu (below) and her lab studied neurons in human epilepsy tissue (above) and mouse models.

LIU LAB; STEPHEN CROCKER/BROWN UNIVERSITY

CARNEY'S CONNECTIONS are highly active through the medical school and also throughout the University. One of Brown's often cited strengths in brain science is the breadth of the faculty and research connections—with up to 45 labs across campus engaged in brain-related research and 130 affiliated professors in departments ranging from neurology and neurosurgery to engineering and computer science.

Undergraduates are also closely knitted into brain science. About a quarter of all Brown undergraduates take the Introduction to Neuroscience course, and many work as research assistants in brain-related campus labs.

CHRISTOPHER MOORE has for eight years been following in the footsteps of Aristotle, working to create bioluminescent tools for neuroscience, and students have been integral to his lab. Bioluminescent light is the glow that can be observed in organisms like fireflies and jellyfish, and it has long fascinated scholars.

More than 2,000 years ago, Aristotle recognized that the generation of light by creatures, and their ability to tolerate bright light, was remarkable. Moore, professor of neuroscience and Carney Institute associate director, and his team at Brown are aiming to use the same kind of chemical light generation to achieve two defining goals of neuroscience: the widespread measurement of brain activity and the control of these same

"HAVING WORLD EXPERTS IN NEUROSCIENCE AROUND ME WILL MAKE THINGS GO FASTER." —Judy Liu

DAVID ORENSTEIN

A DISTINCTIVE APPROACH

Carney Institute faculty and students share thoughts on the distinctive approach to brain research at Brown.

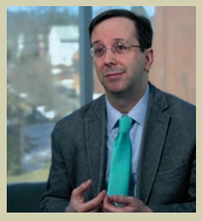
◀ ANNE HART, PROFESSOR OF NEUROSCIENCE

The ability to work with people who want to collaborate and who are good at talking to others is critical.

I look at our work on ALS now, where we have…clinical researchers who can work together across systems, using the strengths of each one, and people who are willing to work together to move our understanding of this disease forward to try and figure out what are the right targets for drugs, figure out why neurons die. …And I see that we could replicate that for sleep, for other diseases, for understanding consciousness, for understanding learning and memory. Then we'll make leaps forward.

BELINDA MAHAMA, PHD STUDENT IN NEUROSCIENCE ▶

My research is collaborative in the sense that if I want to try a new technique, [Brown] has the mentors and funding to help me…It gives a lot of aspiring scientists the chance to try out their ideas without fear of not having the support that they need. And it provides the space for creativity.



◀ LEIGH HOCHBERG '90, PROFESSOR OF ENGINEERING

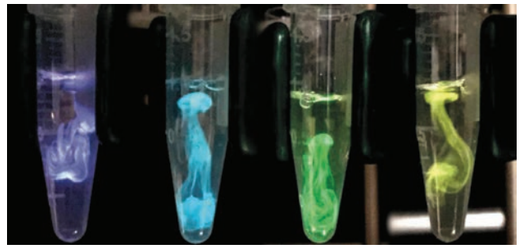
BrainGate is an incredible example of basic science that started here at Brown, a fundamental understanding of the nervous system and of movement, and translating that all the way through to clinical trials and, hopefully, to a device that will one day restore the ability to communicate and to move. To do all of that, from A to Z, to have that depth of expertise in neuroscience and engineering and applied mathematics and computer science—there are very few places in the world that can do that. We're very lucky that we can do that here at Brown.

MAYA SINGH '19, RESEARCH ASSISTANT ▶

I have been really impressed by the accessibility of many professors in brain science at Brown and just their willingness to collaborate and discuss, especially with young scientists like myself. I found that to be probably one of the most motivating factors to continue going forward.

STEPHEN CROCKER (4)

Christopher Moore is a leader of a team working to advance technology giving nervous system cells the ability to make and respond to light.



Four tubes contain the ingredients that produce bioluminescence.

"THERE ARE LITERALLY NO BOUNDARIES FOR WORKING ACROSS DISCIPLINES, WHICH IS WHERE THE EXCITING THINGS HAPPEN."

—Diane Lipscombe

BROWN UNIVERSITY; NATHAN SHANER

neurons. The impact of bioluminescent tools could ultimately aid in diseases—in Parkinson's, for instance, the light could make cells less hyperactive, helping treat patients.

Moore and Brown recently received a grant of up to $9.2 million from the National Science Foundation's NeuroNex program to lead a national center to disseminate such tools, in collaboration with Central Michigan University and the Scintillon Institute. The group is spreading knowledge through workshops and other avenues of the burgeoning global "open science" movement, putting Brown at the forefront of efforts to break down information barriers.

While discoveries along the way have been important, Moore seems proudest of two instances of collaboration that have dramatically driven the project.

The first pivotal joint effort came in 2011, when Moore was new to Brown. While they had come up with the initial ideas, he and a postdoc knew their lab was not equipped to do the needed testing. They decided that Lipscombe, a senior colleague, was best positioned to assist them, but they were nervous about making such a request of an established colleague. Moore recalls walking down the hall and shyly knocking on her door. After he spoke, Lipscombe calmly said, "The way to test it would be this." And, Moore remembers, "she had all sorts of ideas." Within a week, the two labs were working together and had initial evidence that bioluminescence could control cells. It was "the Brown way," he came to see, where collaboration is the norm.

Another critical partnership developed the following spring. A key early collaborator with Moore was a colleague at Duke, who heard that another Duke researcher, Ute Hochgeschwender, was working on something similar. Moore spent money from a grant to fly Hochgeschwender to Providence to give a lab talk. "She was just fantastic," he said, and they decided to collaborate rather than compete, an enduring relationship that continues with Hochgeschwender now at Central Michigan University.

IN 2018, MANY SIGNIFICANT RESEARCH STEPS were taken at Carney—including those led by Barnea, Liu, and Moore—and collaboration was an essential thread, Lipscombe said. She said collaboration infuses and elevates work throughout Carney.

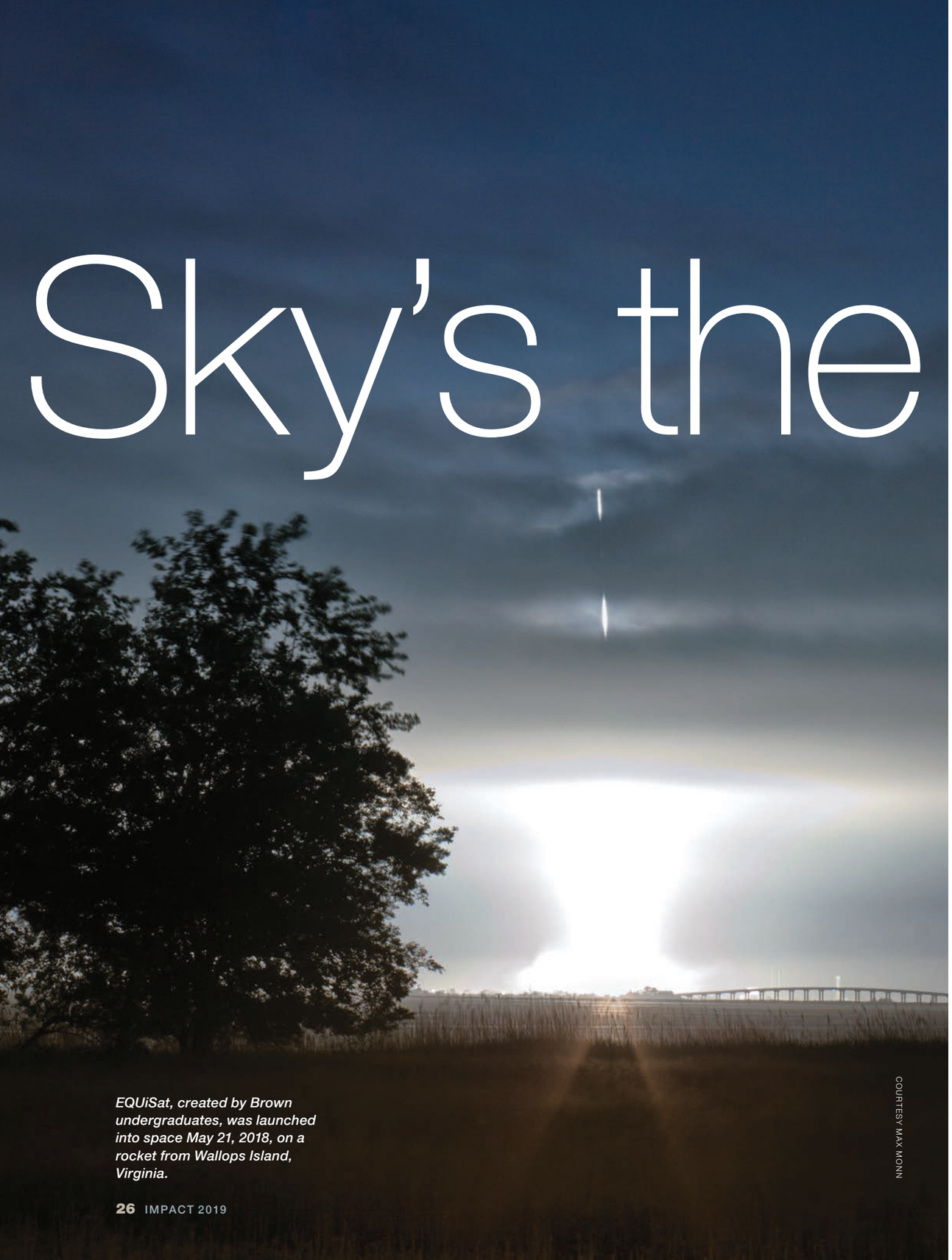
The National Institutes of Health announced in the fall of 2018 a $12 million renewal for the next five years for the Center for Central Nervous System Function, part of the Carney Institute and led by neuroscience professor Jerome Sanes. The grant will launch five new research projects across many departments and further develop analysis tools to advance brain science at Brown.

"There are literally no boundaries for working across disciplines, which is where the exciting things happen," Lipscombe said. "We don't see boundaries." ■

Sky's the Limit

BY SARAH C. BALDWIN '87

From building a satellite to exploring immunology, virtual reality, and more, undergraduates are engaged in ambitious research.



COURTESY MAX MONN

EQUiSat, created by Brown undergraduates, was launched into space May 21, 2018, on a rocket from Wallops Island, Virginia.

When asked about the recent success of a student-led aerospace project called EQUiSat, Brown planetary scientist James Head '69 PhD said he isn't surprised—he's impressed: "Brown undergrads have done the impossible: They have designed, built, and launched a satellite with the audacious goal of bringing space to the people. What could be more 'Brown' than students dreaming an impossible dream and then making it a reality?"

Whether for the summer, the semester, or the academic year, collaborating one-on-one with a professor or with an interdisciplinary team, writing a thesis, or working on an independent study project, at any given point more than 1,000 Brown undergraduate students are conducting research in labs, libraries, and the field.

If Brown is a hotbed of research opportunities for undergrads, said Oludurotimi Adetunji, dean of undergraduate research and inclusive science, it's because "students are seen as equal partners and cocreators. Their voices and contributions matter."

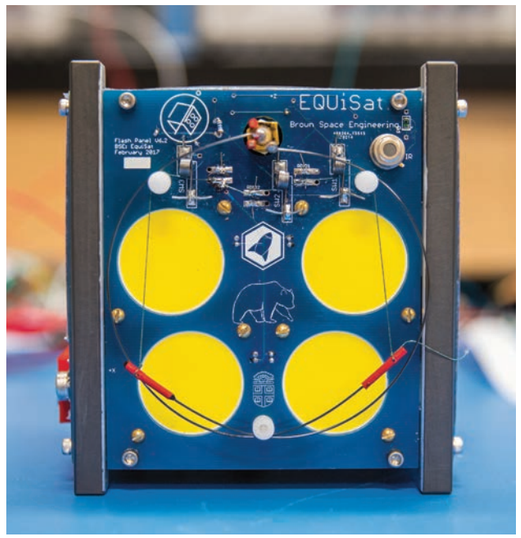
Their work is not going unnoticed. In fall 2017, two recent graduates were among the 25 cited as having written the top undergraduate research papers by the prestigious Undergraduate Awards—the largest academic awards program in the world, with 6,432 applicants from across the globe that year. Seventeen additional papers by students and recent alumni were "highly commended."

And in November 2018, Rhea Stark '18.5 was awarded a Rhodes Scholarship, one of only 32 in the country. She was a dual concentrator in archaeology and the ancient world and Middle East stud-

ies, and the Rhodes Trust said about her work as a researcher that she "uncovers buried histories by elevating the narratives of everyday people, particularly women and people of color."

For Dean of the College Rashid Zia '01, student research is important because "these opportunities help to actively engage students in one of our core missions—discovering and sharing knowledge. Research not only helps students better understand the specific topic of their projects, but also reinforces the power of inquiry. They can appreciate the dynamic nature of knowledge and see how their own effort can advance understanding."

All Systems Go



A 4-inch cube, Brown's EQUISat was deployed by International Space Station astronauts July 13, 2018.

Imagine gazing up at the night sky and knowing that somewhere arcing across it is a satellite that you helped build. As of summer 2018, that's a pleasure that some 80 former and current Brown students got to experience, along with the knowledge that they are advancing science.

The idea for the spacecraft, a four-inch cube called EQUiSat, was born in 2011, when a handful of students in an aerospace engineering class decided to try to design and launch a satellite. With a budget of less than $5,000, the team got right to it, building and testing the parts and systems themselves.

Seven years later, in May 2018, thanks to the work of successive generations of undergraduates, EQUiSat was included on a NASA resupply mission to the International Space Station, lifting off in a commercial rocket while dozens of the students watched on Wallops Island, Virginia. Then, in July, astronauts successfully launched it into space, where it joined the select group of other, decidedly non-DIY satellites orbiting the earth.

The tiny craft came equipped with a mission. It was outfitted with four industrial LEDs powered by lithium iron phosphate ($LiFePO_4$) batteries, which have never been flown in space. NASA will use the batteries' performance data to determine their viability for future space suits and rovers. The agency has also mandated testing of the satellite's ability to survive a trip into orbit and to function properly some 250 miles above the earth.

EQUiSat's other mission was to show people that space is accessible—not just to those in the space industry, but to all. It emitted a signal that both complex ground stations, including the special antenna installed on the cupola of Brown's Ladd Observatory, and amateur radio users have been picking up. The LEDs were set to flash as brightly as the North Star at regular intervals, encouraging people to look skyward and, the team hopes, post sightings on Facebook and Twitter. These features, coupled with the cube's low final cost of $3,776 and open source system (available on the team's website, along with K–12 curricula for budding space amateurs), are proof positive, according to the student designers, that space technology is within reach.

NICK DENTAMARO/BROWN UNIVERSITY (2)

Lauren Haller '18 works on EQUiSat's aluminum chassis, custom-milled by the team.

Yoel Zaid '19 (left) and Noah Joseph '18 lay out pieces for EQUiSat at the Engineering School's Brown Design Workshop.

"Although we had advisers... we mostly learned from each other." —Lauren Haller '18

Brown Space Engineering, as the team is called, has been entirely student-run from the start, says Lauren Haller '18, who machined the chassis. "Although we had advisers and reached out to a few experts [including Rick Fleeter, an adjunct associate professor of engineering at Brown], we mostly learned from each other." Different teams within BSE had to engineer the complex chemical coating for the delicate solar panels, for example, and design the computer code to run the systems.

"Each generation of leadership has channeled their excitement toward a different part of the project," says Hannah Varner '14, a member of the team that successfully applied to NASA for a spot on a rocket in 2014. "With a fair bit of luck, we have accomplished something that none of us ever believed was possible."

A number of last-minute challenges made for lots of long hours for team members as the launch approached. But in the end, said Hunter Ray '18, the team's project manager in the months before launch and an engineering concentrator like many of his colleagues, the team pulled together and delivered. "It was hard to say, 'Hey, I know you have three finals coming up and a paper due tomorrow, but we need you to come in and work on this,'" Ray said. "But it really pushed us. I think as a team we came out stronger."

Growing in the Lab

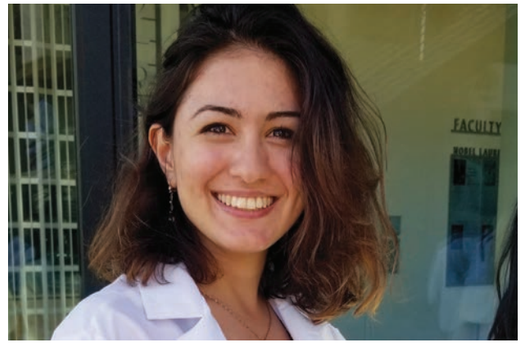
NICK DENTAMARO/BROWN UNIVERSITY; COURTESY LILIT GRIGORYAN

Growing up in Armenia, Lilit Grigoryan '18 thought she wanted to be a doctor like her mom. But working in Professor Laurent Brossay's lab at Brown was a revelation.

There she discovered not only her love of scientific research, but also a community of "helpful, smart, collaborative people." These include the grad students who trained her, as well as Brossay himself.

After a year and a half of doing experiments in Brossay's lab, Grigoryan thought she had reached a dead end. She had been looking at a category of lymphocytes—the white blood cells that are part of the immune system—called cytotoxic T cells. These are responsible for the removal of the human body's own cells that have been infected by viruses or taken over by cancer. She was trying to identify the function of a lipid marker found on them, but was unsuccessful. "I was disappointed," she said, yet gamely decided to write a thesis about it anyway.

Then, as she was reviewing data from the year before, something jumped out at her.



Lilit Grigoryan '18 is now pursuing a PhD in immunology.

"These world-class professors... treated us as their equals." —Lilit Grigoryan '18

She realized she was looking at a new marker, one that was present solely on white blood cells that were producing the highly inflammatory interferon gamma, which plays a role in combating viruses. Dubbed CD27, the marker could be used to identify this subset of T cells in an individual battling a viral infection, eventually leading to novel immune interventions. That quickly became the topic of her thesis, for which she received both the Clapp Prize for Outstanding Undergraduate Thesis and the Elizabeth Leduc ['48 PhD] Prize in Cell Biology, named for the distinguished scholar and former dean of biology at Brown.

Grigoryan said that, as a mentor, Brossay, who is chair of molecular microbiology and immunology, was deeply involved with her work. "He taught me every cell shape I needed to know and helped me design new experiments." And he included her as second author on a paper his lab recently published. It stunned her that at Brown she "met these world-class professors who treated us as their equals." For his part, Brossay counts Grigoryan among the most accomplished of the thousands of undergrads he has taught over the past 18 years.

Fascinated by the "cross-talk" of the immune system with other parts of the body, Grigoryan is pursuing a PhD in immunology at Stanford and is on her way to becoming, if Brossay's prediction comes true, "a highly visible scientist."

The Right Study at the Right Time

When you think of probiotics—foods containing the microorganisms that help our bodies function properly—kimchi might not come immediately to mind. But, along with yogurt and kombucha, the traditional Korean side dish of fermented cabbage is an increasingly popular probiotic choice. Because it's usually made with fish sauce, though, vegans haven't been able to tap into health benefits it may offer.

So it was significant when a recent study that attracted considerable attention, published in the peer-reviewed journal *Food Microbiology*, showed that, though they start out with different microbial communities, vegan kimchi ends up with almost the identical type of bacteria after fermentation as the traditional kind. The results were seen as exciting, yet even more surprising to some was that the lead author, Michelle Zabat '18, was a senior at Brown when the study came out.

Food has always been so central to the life and identity of this Filipina-American that she created a food studies track within her health and human biology concentration. "I was very interested in the intersections between culture, health, science, and society. Food presented a way of exploring the overlaps between all of these things," she said.

Zabat credits her mentor, Assistant Professor of Molecular Microbiology and Immunology Peter Belenky, with validating her interests. "When it came time to start thinking about my senior thesis project," she said, "he suggested I merge my passion for food science with the human microbiome work his lab traditionally focuses on"—that is, the impacts of microbial community dynamics on human health. Working with grad students Damien Cabral and Jenna Wurster and research assistant William Sano, Zabat obtained vegan and nonvegan bacterial samples from a local fermenter and used high-throughput DNA sequencing to identify the bacteria.

According to Belenky, Zabat's taste in research is as good as her timing. "Microbial communities, fermentation, and veganism—these are areas people are very interested in right now," he said. "Michelle hit all of those notes."

And her interests were no mere flash in the pan: thanks to a U.S. Fulbright Student Research Award, Zabat traveled to the Philippines after graduation to continue studying traditional Filipino fermented foods.

ISTOCK

Michelle Zabat '18 conducted a study on kimchi that earned international scientific attention.

COURTESY NELLIE ROBINSON

"Toymaker," a 7-minute animated short, has been accepted into many international film festivals.

#Teamwork

In fall 2015, when Brown/RISD student Nellie Robinson '17 asked computer science lecturer Barbara Meier '83, '87 ScM if she could design a class that would produce an animated film, Meier said yes, as long as she had at least 10 people on the project.

Over the next year, Robinson developed the art, storyboard, and script and gathered the collaborators. The class, Advanced Animation Production, kicked off in fall 2016. Eight months and 10,000 computer hours later, *Toymaker*, a seven-minute animated short, was complete. And in 2018, the film won the music award in the student competition at Athens Animfest and was accepted into five more festivals, including the Los Angeles International Children's Film Festival.

"It was a student-driven process," said Robinson. "We were responsible for setting our own schedule and leading our own critiques, with Barb to guide us with practical advice. Everything we made was from scratch, from story and concept all the way through production. This gave us a sense of ownership that was crucial for staying invested in our work."

"The format of Barb's course allowed each of us to focus on certain areas of the pipeline that interested us the most, while collaborating with each other and providing feedback, all in the format of a small animation studio," said Kenji Endo '18, who helped lead on modeling and set dressing. In 2017, Endo completed another research project with Meier, developing new curricular materials and tutorials for Meier's course Intro to 3D Computer Animation.

According to Meier, a well-designed course structure alone was not enough to guarantee the success of *Toymaker*. "These students had a vision for their piece and created a tight community that made the process rewarding enough to continue even when some of the work was tedious," she said. "The heartwarming story of the film stands by itself, but for me it will always be interwoven with the story of friends working toward a common goal."

"This gave us a sense of ownership that was crucial for staying invested in our work."
—Nellie Robinson '17

Back to the Virtual Future

When Adam Blumenthal, Brown's virtual reality artist-in-residence, launched into an immersive virtual reality (VR) project focused on the Gaspee Affair, it wasn't long before a team of undergraduates volunteered to pitch in. A year later, he and 14 students formed a group independent study project titled Virtual Reality for Education.

When completed, the project will be used to teach middle and high school students about the 1772 incident in which Rhode Island colonists boarded and burned the HMS *Gaspee*, a British Royal Navy schooner helmed by a captain with a reputation for confiscating cargo and harassing merchants and fishermen. The incident was significant in the run-up to the Declaration of Independence.

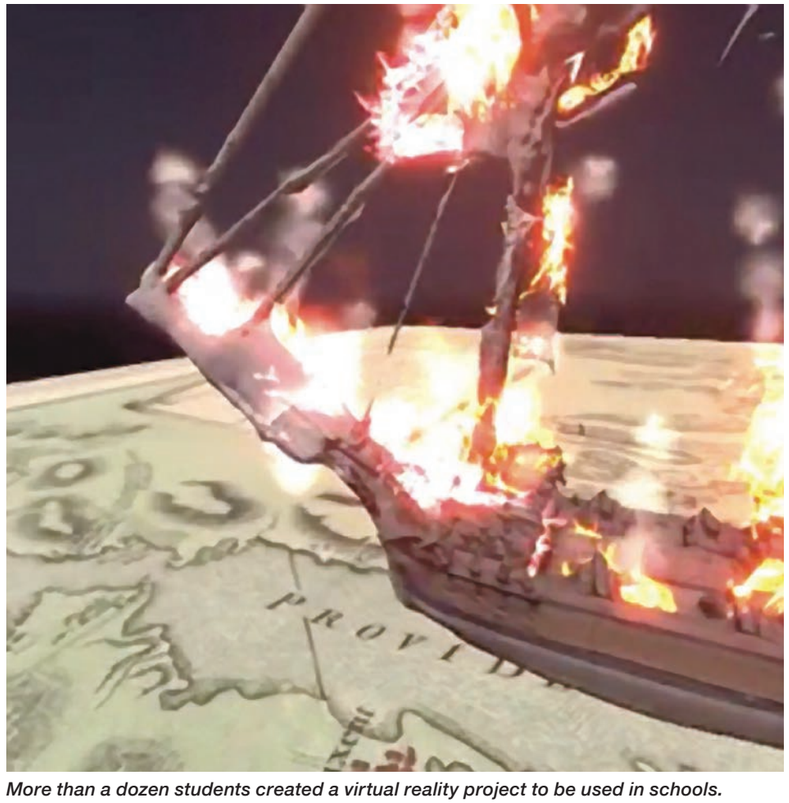
To create such a product is no small undertaking, according to Blumenthal, but the project's "14 creative minds"—concentrators in more than a dozen disciplines, from computer engineering to visual art—"were great collaborators."

Students had to think hard about how to structure the project so it was manageable to produce and also met the educational requirements. "We were really focused in the beginning on how you could put this into a curriculum," said Zev Izenberg '20, a computer science and visual art concentrator. "By the end, we realized how difficult it was to create anything at all in VR. …The hard stuff is getting it there in the first place."

Creating the project involved historical research, script writing, reenactments of historical scenes, animation, 3D modeling, coding, and learning how to use new and emerging VR programs. The team shot the scenes using a 360-degree Google Jump camera rig that the company loaned to Blumenthal, a designated "trusted tester" of Google VR technology.

The production also involved Tilt Brush, a Google VR painting program, and a technique called photogrammetry, which figures out the geometry or shape of things in the environment. Students wove all these elements throughout the storytelling process, adding voiceover narration and using spatial audio to guide a student through the experience.

The sense of being immersed in an environment where history is being made makes VR an effective tool for overcoming disengagement among students, said Blumenthal. Hannah Seckendorf '20, a cognitive science concentrator, agreed, saying that VR is often referred to as an empathy machine. "Students [can sometimes feel] that the material they're studying isn't relevant, or that it has no importance in daily life. In VR, it is relevant to you, because it's your environment."



More than a dozen students created a virtual reality project to be used in schools.

COURTESY ADAM BLUMENTHAL

Katerina Ramos Jordan (right) studied Puerto Rican literature and presented at Brown's annual summer research symposium.

NICK DENTAMARO/BROWN UNIVERSITY

Shelter from the Storm

Katerina Ramos Jordan arrived at Brown on an October evening in 2017, not long after Hurricane Maria had devastated a swath of the Caribbean—including Puerto Rico, her home. Brown welcomed her and other displaced University of Puerto Rico students.

Over the course of the academic year, Ramos found a "passionate and collaborative community," and wanted to stay for the summer and continue her work. "I knew Brown was the perfect place that would allow me to conduct my research in a unique and interdisciplinary way," she said. So she applied to a summer research program run by the Leadership Alliance, a Brown-based consortium of 36 premier research and teaching institutions that supports underrepresented and underserved students who want to explore advanced graduate study.

Ramos, who studies literature from the Puerto Rican diaspora, worked with Leticia Alvarado, an assistant professor of ethnic studies and American studies at Brown. "We connected immediately," she said of her mentor. "She motivated me constantly to analyze in depth and to express my ideas clearly. Exchanging ideas with her was a continually enriching process."

"Brown was the perfect place… to conduct my research in a unique and sciplinary way." —Katerina Ramos Jordan

Many more students like her will be able to enjoy the same support. The Mellon Foundation recently gave $1.25 million to the consortium to underwrite summer undergraduate research in the humanities and social sciences for underrepresented students. That funding will support students at the 10 host universities—Brown, Columbia, Harvard, Yale, Stanford, New York University, University of Chicago, University of Virginia, University of Pennsylvania, and Johns Hopkins University—that are part of the Leadership Alliance Mellon Initiative.

Leadership Alliance director Medeva Ghee said that exposing these students to challenging research and competitive graduate programs means that more will choose the doctoral path, thereby diversifying the academy, government, and industry. That's certainly the case with Ramos. "I plan to continue developing my research, prepare for graduate school, and, hopefully, become a professor," she said. "Being part of the Leadership Alliance has made me believe that with discipline, work, and patience I can achieve that."

THE POWER OF TRUTH

The Center for the Study of Slavery and Justice looks at the past at Brown and beyond to move forward.

Brown commissioned sculptor Martin Puryear to create the Slavery Memorial on its Quiet Green.

BY GILLIAN KILEY

When Brown's Center for the Study of Slavery and Justice (CSSJ) opened in 2012, it immediately launched a rich yearlong series of programs that asked critical questions about the transatlantic slave trade, its legacies, and its ramifications for the present.

What were the conditions on the ships used to bring slaves to America? What kinds of knowledge did enslaved people create? What are the links between slavery and present-day phenomena like racial profiling and human trafficking?

While new centers are often forgiven for slow, deliberate start-up periods, the CSSJ had anything but that, drawing crowds to its many initial events. Then, as now, its programs enabled Brown and the larger community to ask big questions about subjects often suppressed.

"The CSSJ is a center in the world," said Anthony Bogues, the CSSJ's founding director. "It does not just reside in the academic space. The academy tends to be isolated from the world, but we are engaged with it. We have no other option, because the issues and questions we work on demand rigorous scholarship and are critical to the world we live in today."

The CSSJ generates original research, projects, and programs that address pressing issues related to slavery and its legacies, from questions about memorials perceived as racist

BROWN UNIVERSITY; JOHN HAY LIBRARY

In partnership with the International Slavery Museum in England, Brown was the first institution in the United States to exhibit these slave shackles, which were on view at the John Hay Library in 2016.

to how race impacts health disparities to the status of voting rights today.

TRUTH IN ALL ITS COMPLEXITY

To serve its public humanities mission, the CSSJ constantly reaches beyond the walls of Brown, Bogues said. The work often involves partnering with other academic and cultural institutions or bringing distinguished scholars and others active in civil and workers' rights movements to Brown. But its foundation is tied inextricably to the University's efforts to grapple with its own history through the work of its Steering Committee on Slavery and Justice, commissioned in 2003 by then-President Ruth J. Simmons.

Simmons asked the committee to examine the University's historical entanglement with slavery and the slave trade. In 2006, the committee issued its report, which detailed how Brown alumni, Corporation members, and members of its namesake family participated in the slave trade, and it catalogued the objects, buildings, and images on campus that honored those involved.

Anthony Bogues, founding director of the Center for the Study of Slavery and Justice, works with organizations around the world interpreting slavery.

The report was a watershed moment, scholars around the world say: In publicly confronting the University's direct ties to slavery, Brown openly addressed its past and examined how that past impacts the present. Among other recommendations, the committee suggested creating a center that would continue the work of confronting traumatic histories and, as Simmons said, "tell the truth in all its complexity."

Brown has been credited with inspiring similar efforts at many other institutions. The Rev. David Collins, associate professor of history at Georgetown University, said that Brown's process for telling the truth about its past, and identifying a means of taking responsibility for it, was revelatory. When Collins was asked in 2015 to chair Georgetown's Working Group on Slavery, Memory and Reconciliation, he said "reading Brown's report was one of the first things I did."

"Brown showed how a university could tap into the problem in a manner proper to a university," Collins said, by "using its greatest resources," including the ability to conduct in-depth research, encourage learning, and develop relationships.

Brown's "pioneering" work "has long stood as the gold standard for how to embark," according to the website of the Universities Studying Slavery consortium convened in 2014 by the University of Virginia and which now has 45 members.

As the CSSJ marks the conclusion of its first five years, its faculty, staff, and students continue to expand the center's robust research and public-facing initiatives in ambitious collaborations involving many academic departments and other organizations.

The CSSJ is home to a number of research clusters focused on slavery and abolition, contemporary human trafficking, a comparative history of slavery, the American criminal justice system, and structural racism in biomedicine.

The latter is led by Lundy Braun, a professor of medical science and Africana studies. With faculty and students from history, sociology, American studies, Africana studies, public health, biology, and Brown's Warren Alpert Medical School, the group researches the history of race and racism in medicine. An area of great concern, Braun said, is how fixed ideas about race impact the diagnosis and treatment of disease.

The CSSJ's research clusters have already produced many exhibition catalogs, launched undergraduate research projects, created curricula for high school educators, and convened networks of scholars, Bogues said.

GLOBAL AND LOCAL IMPACT

Because slavery and the slave trade had "world-historic proportions," Bogues said, the center works with institutions across the globe in its efforts to bring rigor to the way the history of slavery is studied and presented. With the Smithsonian Institution's National Museum of African American History and Culture, the CSSJ convenes the Global Curatorial Project, a group of curators from major museums in South Africa, Senegal, the United Kingdom, France, Belgium, the Netherlands, and the United States.

The group's members initially met in 2014 to discuss how they had curated prior exhibitions on slavery and colonialism. Now, they are developing new institutional practices to encourage the communities they serve to shape how exhibitions about the legacies of slavery are told.

The CSSJ has also established itself as a resource for other public projects in media. Award-winning director Stanley J. Nelson Jr., who has examined the history and experiences of African Americans in films like *Freedom Riders*, enlisted the help of the CSSJ for a forthcoming documentary that will chart the economic and human cost of the slave trade.

Bogues said the slave trade and its economic, social, and political consequences on multiple continents remain not fully understood, and the CSSJ worked with Nelson's Firelight Media to bring together the best scholarship. According to producer Naz Habtezghi, partnering with the CSSJ was critical to the team's effort to spotlight this untold story while honoring the complexity and humanity of its subject.

The work of the CSSJ and the Steering Committee has also changed how the history of slavery is represented locally. Sean Siperstein '05 was a member of an undergraduate group project that worked in tandem with the Steering Committee on Slavery and Justice. The students researched and created an exhibition on the *Sally*, a slave ship owned by Brown family members. During a 1764 voyage, Captain Esek Hopkins captured 196 Africans to be auctioned off as slaves, the exhibition explains, and at least 109 of those Africans died en route.

Siperstein recalled visiting the John Brown House—the historic home of one of the family members who owned the ship—as an undergraduate and asking the tour guide there about John Brown's role in the local slave trade.

"There was nothing about slavery in the display materials," Siperstein said. "I think my question made the tour guide nervous."

At that time, there seemed to be hesitancy about openly addressing local involvement in the slave trade, Siperstein said. But now, because of the work of the Steering Committee and CSSJ, the *Sally* exhibition that Siperstein worked on is on display at the John Brown House, and Brown Family Weekend programming includes a Slavery and Legacy Walking Tour of Providence that was designed by two high school-aged CSSJ interns.

Beyond internships, Bogues said the CSSJ frequently engages with students through tours and exhibitions and through its Civil Rights Movement Initiative (CRMI), in which students from Providence's Hope High School take a six-week course and spend a week traveling to historic sites in the South, meeting with movement veterans.

> BROWN'S "PIONEERING" WORK "HAS LONG STOOD AS THE GOLD STANDARD"
> —Universities Studying Slavery consortium

"I have been teaching in Providence for 28 years, and I have seen few programs with the impact of CRMI," said Jonathan Goodman, a teacher at Hope High.

Embarking on a journey that is both intellectual and often emotional is not always easy for students, said Sara Jackson, a CRMI participant who is now a student at Providence College.

"I was reluctant to join," Jackson said. "I was very aware of my ignorance, and I didn't want to confront the emotions that go hand in hand with learning your history. This trip taught me that, in the end, what you do with the lessons you learn, good or bad, is what makes you a brave person."

For Siperstein, who is engaged with the work of the CSSJ as an alumnus and as cochair of Friends of the CSSJ, the center's work is energizing, in the center's existence fulfills the promise of the Steering Committee's efforts.

"The entire idea of the Steering Committee's charge was to grapple with history as a University, as a continuous subject, and then not just grapple but take these steps," Siperstein said. "That we want to understand and learn from the past is reflected in the center's existence, in its work and mission."

BROWN UNIVERSITY

FOCUS

A CLOSER LOOK AT RESEARCHERS AND PROJECTS GAINING WIDER INFLUENCE

Information Ultra-Highway

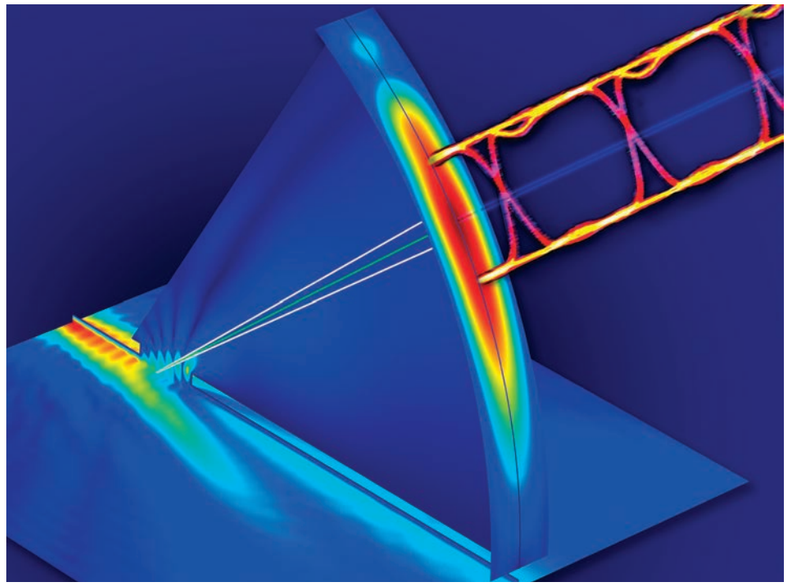
Transmitting data via terahertz waves shows promise in unclogging the data logjam.

BY KEVIN STACEY AND NOEL RUBINTON '77

When Alexander Graham Bell transformed communications with the telephone in the 1870s, he had an assist from two Brown professors—Eli Whitney Blake and John Peirce—whose work on a phone receiver was ultimately adopted by Bell.

With the revolution in communications now going at speeds that Bell could never have imagined, another Brown professor—Daniel Mittleman in the School of Engineering—is working with colleagues to find a way to solve a critical logjam on the modern-day information superhighway.

Today's cellular networks and Wi-Fi systems rely on microwave radiation to carry data, but the demand for more and more bandwidth is rapidly becoming more than microwaves can handle. That has researchers thinking about transmitting data on higher-frequency terahertz waves, which have as much as 100 times the data-carrying capacity of microwaves.



MITTLEMAN LAB/BROWN UNIVERSITY/DUCOURNAU LAB/CNRS/UNIVERSITY OF LILLE

A simulation of radiation emerging from a terahertz multiplexer. Terahertz could enable the next generation of ultra-high-bandwidth networks to handle more data.

Mittleman is at the forefront of those exploring the field of terahertz technology. Though terahertz transmission remains in an early stage, with much basic research to be done and plenty of challenges to overcome, Mittleman is leading many key avenues of investigation. He and his colleagues are working to develop the basic components and techniques needed to make terahertz communications a reality.

Multiplexing, the ability to send multiple signals through a single channel, is a fundamental feature of any voice or data communication system. An international research team led by Mittleman has demonstrated for the first time a method for multiplexing data carried on terahertz waves, which may enable the next generation of ultra-high-bandwidth wireless networks.

"The terahertz range is often called the 'last frontier' of the electromagnetic spectrum, since it is the least well explored range of the spectrum," Mittleman said. "There's a good reason for this: everything is more challenging in this range, including generating the radiation, manipulating it, and detecting it. But, with these challenges, there are also tremendous opportunities for new science and new technologies."

In the journal *Nature Communications*, Mittleman and his team reported the transmission of two real-time video signals through a terahertz multiplexer at an aggregate data rate of 50 gigabits per second, approximately 100 times the optimal data rate of today's fastest cellular network. "We showed that we can transmit separate data streams on terahertz waves at very high speeds and with very low error rates," Mittleman said.

"There are also tremendous opportunities for new science, and new technologies."

—Daniel Mittleman

Mittleman and his team have even made the streets of Providence near their Barus & Holley offices a literal living laboratory. They have conducted measurements under the first license from the Federal Communications Commission to perform outdoor tests of data transmission in several frequency bands in the terahertz range. "These kinds of outdoor tests will be important for understanding what's possible in terahertz communication," Mittleman said.

The first outdoor tests have proven promising, in some cases easing concerns about the versatility of terahertz links. For example, it's long been assumed that terahertz links would require a direct line of sight between receiver and transmitter. But Mittleman and his team showed that non-line-of-sight terahertz data links are possible because the waves can bounce off of walls and other obstacles without losing too much data. Mittleman and his colleagues bounced terahertz waves at four different frequencies off of a variety of objects—mirrors, metal doors, cinderblock walls, and others—and measured the error rate of the data on the wave after the bounces. They showed that acceptable error rates were achievable with modest increases in signal power.

MITTLEMAN LAB/BROWN UNIVERSITY

Brown graduate student Rabi Shrestha works on terahertz testing equipment.

The researchers also looked at what's known as multipath interference. When a signal is transmitted over long distances, the waves fan out, forming an ever-widening cone. As a result of that fanning out, a portion of waves will bounce off the ground before reaching the receiver. That reflected radiation can interfere with the main signal unless a decoder compensates for it. It's a well-understood phenomenon in microwave transmission, and Mittleman and his colleagues wanted to test it in the terahertz range.

They showed that this kind of interference occurs in terahertz waves but to a lesser degree over grass compared to concrete. That's likely because grass contains a lot of water, which tends to absorb terahertz waves. Over grass, the reflected beam is absorbed to a greater degree than over concrete, leaving less of it to interfere with the main beam. That means that terahertz links over grass can be longer than those over concrete because there's less interference to deal with, Mittleman said.

There's also an upside to that kind of interference with the ground. "You can imagine that if your line-of-site path is blocked," Mittleman said, "you could think about bouncing it off the ground to get there."

In other terahertz work, Mittleman and others, including Masaya Nagai, an academic colleague in Japan, have developed a new method of manipulating the polarization of light at terahertz frequencies.

The technique, outlined in a paper in the journal *Scientific Reports*, uses stacks of carefully spaced metal plates to make a polarizing beamsplitter, a device that splits a beam of light by its differing polarization states, sending vertically polarized light in one direction and horizontally polarized light in another. Such a beamsplitter could be useful in a wide variety of systems that make use of terahertz radiation, from imaging systems to future communications networks.

Terahertz radiation is a hot area of study, and the work isn't limited to data transmission. Mittleman and Professor Vicki Colvin from Brown's chemistry department are heading a team that has improved the resolution of terahertz emission spectroscopy—a technique used to study a wide variety of materials—by a thousandfold, making the technique useful at the nanoscale. Laser terahertz emission microscopy is a burgeoning means of characterizing the performance of solar cells, integrated circuits, and other systems and materials.

The researchers believe their new technique could be broadly useful in characterizing the electrical properties of materials in unprecedented detail.

"Terahertz emission has been used to study different materials—semiconductors, superconductors, wide-band-gap insulators, integrated circuits, and others," Mittleman said. "Being able to do this down to the level of individual nanostructures is a big deal."

United States troops stationed in Afghanistan.

GUVENDEMIR/ISTOCK

The Real Costs of War

A project established at Brown has become a key source about the post-9/11 War on Terror.

BY ELENA RENKEN '19

Catherine Lutz, a professor of international studies and anthropology at Brown, was talking in 2010 to Boston University colleague Neta Crawford about the mass of news articles they knew would accompany the upcoming anniversary of 9/11. Despite nearly a decade of fighting the post-9/11 wars, much information on the consequences of these conflicts was still missing.

"People feel they're in the dark about these wars, and why they've been going on so long, and what has happened as a result," Lutz said. "There wasn't a lot of information outside of the official sources of the Pentagon and the White House."

The pair decided to do something to reveal the hidden human, economic, and political costs of U.S. wars since 9/11, so that they could be publicly seen and to inspire a public discussion.

The Costs of War Project was born as Lutz and Crawford gathered a group of scholars at the Watson Institute for International and Public Affairs. Representing many different parts of the United States, as well as other countries, researchers brought with them a wide range of ideas for the project. "Everybody had something really important to say that we had not realized," Lutz said. "No one person has the whole story."

After these conversations, Lutz and Crawford coordinated with scholars to release an initial set of papers in 2011, focused on topics such as health care costs for veterans, the effects of war on Afghan women, and the overcrowding of Iraqi refugees in Arab states. Through a partnership with Reuters, a series of news stories focusing on their research insights was released simultaneously.

While it also assists many other kinds of researchers, enriching the information available to journalists is a central focus of the Costs of War Project, which provides broader perspectives through the dozens of reports it has published in its seven years of operation. The Costs of War Project's research has been referenced by media outlets ranging from the *Wall Street Journal* and the *Times of India* to *The Economist* and *TIME* magazine. The *New York Times* has cited estimates from the project multiple times, including in a 2017 piece from its editorial board pushing for greater government accountability, saying: "The Costs of War project at Brown University estimates over 200,000 civilians have been killed in Afghanistan, Iraq and Pakistan since 2001."

> *"You need to have data and evidence for real accountability."*
>
> —Edward Steinfeld

Though Crawford teaches political science at Boston University, she finished her undergraduate studies at Brown in 1985 and later became a faculty member at the Watson Institute—her long history at the University facilitated smooth coordination with the project being based at Brown. As codirectors, she and Lutz write reports themselves and edit many others before they are published.

"It's not dollars and cents alone, nor is it only blood," Crawford said. "It's also the ripple effects in the economy. We also want to help people understand that the effects of war don't end when the war terminates or when troops are withdrawn."

Stephanie Savell, a research associate at the Watson Institute and the project's third codirector, also focuses on outreach efforts. The Costs of War Project doesn't just generate research; it also strives to connect journalists, advocacy groups, and government officials with their researchers and reports. More than 40 scholars from a range of academic institutions have been involved, with the project centered at Brown where its administrative and editorial processes take place.

The project gained a large amount of attention after publishing Crawford's 2017 report showing that the post-9/11 wars have cost the United States $4.3 trillion and will cost a total of $5.6 trillion once future spending on veterans is factored in, as compared to the Pentagon's $1.5 trillion estimate. Project leaders reached out to U.S. Sen. Jack Reed of Rhode Island, the ranking Democrat on the senate's Committee on Armed Services, and Reed hosted a briefing in the Senate Office Building for journalists and staff representatives from congressional offices.

Costs of War research has been used in Congress numerous times, Savell said, by Republicans and Democrats, including a map the project created showing 76 countries where the United States has taken military action to fight terrorism.

By offering information to policymakers, reporters, and citizens alike, the Costs of War Projects aims to inform assessments of these wars.

More information for the public is always better, said Sebastian Junger, a journalist who has focused on the war in Afghanistan, producing projects like the book *War* and the film *Restrepo*. Few people know that civilian deaths have risen since the United States withdrew troops from Afghanistan, he noted, and added, "It's the kind of information that is crucial if the public is going to make humane and wise decisions about war."

Edward Steinfeld, director of the Watson Institute, said, "It's fundamentally about accountability. It's the accountability of policymakers, the accountability of societies. You need to have data and evidence for real accountability."

"In my view, providing information for general public discussion is what democracy is all about," Steinfeld said. ■

JOSHUA ROBERTS

Costs of War Project codirectors Stephanie Savell (left), Catherine Lutz, and Neta Crawford often make presentations to Congress.

Unpacking Mathematics

ICERM is advancing basic research and the next generation of top scientists.

BY NOEL RUBINTON '77

There was no tightly packed pile of cannonballs at Brown's Institute for Computational and Experimental Research in Mathematics (ICERM) during its semester-long program on "Point Configurations" in 2018. But the famous mathematical question behind such an arrangement was fully present.

Over the course of the spring, more than 300 people in mathematics, physics, and computer science from around the world shared ideas at one of the country's eight mathematical institutes funded by the National Science Foundation. The goals? Stimulating further fundamental research and advancing knowledge.

Looming in the background during deliberations was one of the most enduring problems in mathematics—Kepler's Conjecture, informed by the esteemed 17th-century mathematician and astronomer Johannes Kepler's question: What is the densest way to stack equal-sized cannonballs? The solution to the problem about efficient sphere packing in three-dimensional space may be easy to visualize—an arrangement of fruit at a supermarket is a commonly cited representation—but the theory has proven to be one of mathematics' most difficult to solve rigorously and precisely over the centuries.

The ICERM program included sphere packing along with a variety of related topics. "Point configurations have a lot of real-world applications," said ICERM director and Brown mathematics professor Brendan Hassett. Among the areas related to its study are optimization work such as coding and information theory, modeling the Earth's atmosphere, dense packing of platelets in biology, digital communications, and studying crystallization through which a solid forms.

"ICERM's goal is to develop basic research that can be disseminated widely," Hassett said. Launched in 2010, the research institute is like a think tank with a cast that deliberately keeps rotating. It brings together some of the world's best mathematical minds to explore topics in pure and applied math, computer science, and related disciplines.

In the Point Configurations program, participants made the ICERM offices their base for more than three months, using spaces designed to encourage and support collaborations. From formal presentations to workshops, from spontaneously planned ad hoc programs to conversations over lunch, participants discussed current research questions and started new collaborations.

"One major impact of the program has been to strengthen the internal coherence of this widespread subject of growing importance, which intersects with geometry, analysis, physics, and computer science," said Peter Grabner of Graz University of Technology in Austria, a member of the program's organizing committee.

"New collaborations were formed that have already led to progress on such topics as lattice theory, packing, and statistical physics," said the chair of the organizing committee, Edward Saff, a mathematics professor at Vanderbilt University. Communication among workshop participants is continuing, and a follow-up conference in two years is being considered, as is a new academic journal on the subject.

Leading scholars from around the world attended the program—a few months later, one of the workshop leaders, Akshay Venkatesh of the Institute of Advanced Study in Princeton, was awarded a Fields Medal, an award often described as the Nobel Prize of Mathematics.

BALONCICI/ISTOCK PHOTO

Inquiry into sphere packing started in the 17th century with the study of how best to stack cannonballs.

A large goal of ICERM programs is to develop the next generation of top researchers. "The camaraderie among participants played an important role in the program's success," Saff said. "There were no lines of division between graduate students, postdoctoral students, and senior scientists."

Enhancing the program was intense activity in the mathematical field about its subject in the months leading up to its start. Henry Cohn, a principal researcher for Microsoft Research New England who is also on the Scientific Advisory Board of ICERM, published widely noted research on sphere packing in 24 dimensions. His work was discussed both at ICERM and in a Distinguished Lecture series with him, hosted by the mathematics department at Brown and attended by faculty, undergraduates, and graduate students. The problem of two-dimensional sphere packing was solved in the mid-20th century by Lazlo Fejes Tóth, but it was not solved in three dimensions until Thomas Callister Hales did so in 1998, an accomplishment confirmed by computer check in 2014.

"Fundamental research in the mathematical sciences produces unexpected benefits."

—Jill Pipher

"Fundamental research in the mathematical sciences produces unexpected benefits," said Jill Pipher, Brown's vice president for research, and also founding director of ICERM and professor of mathematics. "The research that is pursued, simply because it pushes the frontiers of mathematical truth further, often pays dividends years and decades later in solving real-world problems," she added.

For instance, she said, number theory, once thought to have no connection to the broader world, eventually led to a new paradigm in encryption and helped make the Internet age imaginable and digital financial transactions possible.

Though by design ICERM programs, which are supported by a five-year, $17.5M federal grant, involve far more visitors than Brown faculty and students, the impact on Brown is large. Dan Abramovich, a professor of mathematics and chair of mathematics, said, "An ICERM program floods Brown with a group of researchers in a particular topic. Our departments and other centers benefit from a supply of seminar and colloquium speakers, concentrated exposure to current research in a particular topic, and a general expansion of the Brown community, often keeping links well after the end of a program." ■

DAVID DELPOIO

Brown chemistry professor Jason Sello says a summer research position while he was an undergraduate sparked his career.

Diversifying Research's Ranks

Brown-based Leadership Alliance aids those from underrepresented groups.

BY O'RYA HYDE-KELLER

In 1995, when Jason Sello was a junior at Morehouse College, he was accepted to a summer research position at Harvard Medical School through the Leadership Alliance, a Brown-based consortium of universities that offers research experiences to undergraduates from groups historically underrepresented in academia.

"That summer at Harvard was a particularly important experience for me," said Sello, now a chemistry professor at Brown. "It gave me more insight into what it would be like to earn a PhD at a research university and also made me see Harvard as a place where I would feel comfortable pursuing graduate education."

Sello proceeded to earn his PhD in biophysics from Harvard before landing at Brown, where his research focuses on the development and mechanisms of drugs, including those aimed at viral infections. In 2011, he received the National Science Foundation's top award for early-career scientists. In 2012, he earned tenure, and in 2018 he became a full professor.

Sello is just one among the Leadership Alliance's many success stories. Convened by then-Brown President Vartan Gregorian in 1992 as a partnership of 23 institutions, the Alliance had a weighty mission: to address the stark shortfall of individuals from historically underrepresented groups who earn doctoral degrees and pursue research careers in academia, the public sector, and industry.

As it passes its 25-year mark, the Leadership Alliance continues to make steady progress toward its goal of diversifying the research world. Besides helping individuals, there's a positive impact on research itself. "The literature is clear that diverse research teams are more effective than homogeneous ones at devising innovative responses to problems," said Medeva Ghee, executive director for the Leadership Alliance.

The Alliance has grown to 36 institutions and industry partners who, to date, have provided more than 4,000 young

scholars with research and networking experiences. More than 460 participants have earned PhDs, and another 388 are currently enrolled in doctoral programs.

Fifty-four percent of Alliance alumni who have earned doctoral degrees are employed in higher education, 58 percent of those in tenure-track positions. Sixty-five percent of those positions are at "R1" universities such as Brown, those classified as having the highest level of research activity.

The Leadership Alliance's flagship program is its Summer Research Early Identification Program. Each summer, it matches at least 320 students from community colleges, liberal arts colleges, and schools that have traditionally served underrepresented students with research experiences at 20 top research institutions, including Brown.

Students conduct research with professors across the disciplines, who mentor them through the experience.

Many undergraduates are first-generation college students who lack previous exposure to research and have little knowledge about academic career paths, said Ghee, also an assistant professor of the Practice of Behavior and Social Sciences at Brown.

"These summer research opportunities at top-notch research universities give these incredibly bright students the tools they need—and a competitive edge—to apply successfully to top graduate school programs," Ghee said.

By diversifying who is conducting research, universities not only advance equity but position themselves to more effectively address the many questions that research poses.

Micah Holness, a Xavier University student who has spent three summers at Brown conducting psychology research through the Leadership Alliance, said the Alliance's lens on diversity has helped her zero in on her professional goals. Research on many mental health disorders often centers less on people of color, she said; someday, she would like to study how treatments for a complex illness like schizophrenia might be improved for underrepresented populations.

"Racial stereotypes and gender stereotypes can affect treatment and diagnoses," Holness said. "Diversifying who is doing research can make solutions more effective for a wider variety of people."

Some institutions—Brown included, through the work of its ambitious diversity and inclusion action plan—are turning that principle into action through other programs as well. Brown's Initiative to Maximize Student Development (IMSD) has markedly increased enrollment and academic achievement among historically underrepresented students in doctoral programs.

"IMSD outcomes have told us to date that student success is all about increasing opportunities, access, and support," said Graduate School Dean Andrew Campbell, who developed the initiative as a faculty member in biology and has worked in recent years to extend it beyond the life sciences.

In 2016, as Brown President Christina Paxson welcomed U.S. Supreme Court Justice Sonia Sotomayor to a Leadership Alliance forum on diversifying America's research workforce, she noted the increased need to advance the mission of the organization founded on Brown's campus.

"The work of the Leadership Alliance is a great complement to efforts at Brown and at other research institutions," Paxson said, "and this is a critical moment for us to use our leadership roles to influence higher education and our nation in a positive direction regarding the challenges and demands of diversity."

A Hard Drive in a Test Tube?

Team is developing a new way to store vast amounts of data.

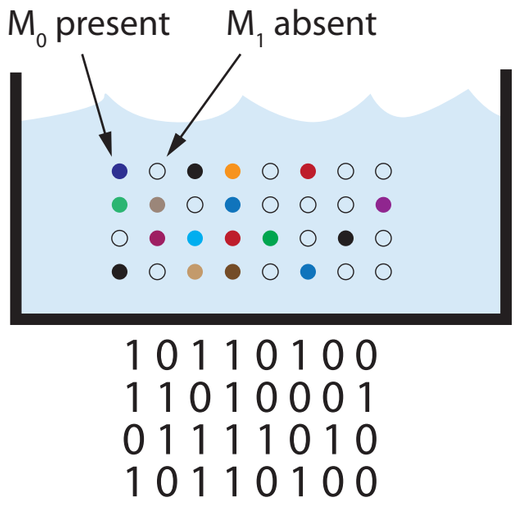
BY KEVIN STACEY

The world's ability to produce and collect data is quickly outpacing the ability to store it. Analysts estimate that, by 2040, the world will have produced 3 septillion bits of digital data—that's 3 followed by 24 zeros. There simply won't be enough microchip-grade silicon on the planet to store all that on solid-state memory chips.

The ever-expanding digital universe has many scientists thinking about new ways to stash data. Supported by a $4.1 million award from the U.S. Defense Advanced Research Projects Agency (DARPA), a team of Brown chemists and engineers is working to store data in a way that's never been tried before: by encoding information in unique molecules dissolved in solutions. The approach has the potential for storing colossal amounts of data in a mere droplet of solution.

AMY SIMMONS

A multidisciplinary faculty-student lab team is led by professors Jacob Rosenstein of engineering (first row, center) and Brenda Rubenstein of chemistry (to right).



RUBENSTEIN LAB

Digital data can be seen as a string of 1s and 0s. By connecting those digits to the presence or absence of molecules in a solution, information can be encoded in liquid.

"If each molecule dissolved in a flask holds one byte of data, then we could store the equivalent of many billions of one-terabyte hard drives," said Brenda Rubenstein, an assistant professor of chemistry and project coleader. "That's far more compact than any type of storage we have today."

The core concept behind the project is straightforward: Use the presence or absence of specific molecules in a solution as ones and zeros, the components of digital data. The challenge is in the details—finding efficient ways to synthesize the millions of unique compounds needed to encode complex datasets, precisely mixing complex solutions and accurately probing those solutions to retrieve the data once it's encoded.

Since receiving the DARPA award in January 2018, the team has been working on those issues. To make their molecules, they're using Ugi reactions, a method used in the pharmaceutical industry to generate millions of possible drug candidates. They've acquired two liquid-handling robots to automate mixture-making, and they've purchased one of the most powerful mass spectrometers in New England to detect dissolved compounds and retrieve encoded data.

"This project started out really as just ideas and concepts," said Jacob Rosenstein, an assistant professor of engineering and project coleader. "But now we're starting to use these new experimental tools and get some results. It's starting to feel a bit more real."

And they've made significant progress. As a proof of concept for DARPA, the team encoded an 81-bit image into a solution last year. Now they're up to kilobytes and climbing. So far, Rubenstein said, they've not hit any showstoppers in terms of scaling up to larger datasets. They have a sense, however, where some roadblocks might emerge.

"We'll eventually hit a point where liquid-handling robots just can't move their arms fast enough to make the mixtures we need in a reasonable amount of time," Rubenstein said. "So we're thinking about ways to get over that hump using engineering and chemistry. We still have to do some analysis to better understand which approaches will move us forward."

The team has also made strides in another of the project's objectives, which is to perform actual in-solution computations on the data they've stored. In recently published research, the team showed that solutions can be used to build perceptrons. You can think of a perceptron as the simplest form of artificial neural network, the systems that power modern artificial intelligence.

> ***"This is really a grand challenge problem that requires different perspectives from everybody."***
> —Brenda Rubenstein

For their study, they used molecular perceptrons to perform rudimentary machine learning tasks. After encoding images of handwritten letters and numbers into solutions, the researchers showed that the solutions could be used to learn which symbols were what.

"The chemicals were actually doing a little bit of handwriting analysis," Rosenstein said. "We could have them answer basic questions like: 'Is this a picture of a handwritten number one or a number two?'"

Miraculous as that might seem, the researchers know there's much work to be done before molecular storage and computation devices are a practical reality.

"What we're working on here is a foundation of new ideas, rather than a product that's going to be on the market next year," Rosenstein said. "But we're getting better every day, and we're happy with our progress."

Rubenstein said she's confident that the diversity of perspectives and expertise among the researchers puts them in a solid position to continue that progress. The team of professors, postdoctoral researchers, and students is attacking the problem from multiple vantage points—chemistry, engineering, information theory, robotics, and computer-aided design.

"This is really a grand challenge problem that requires different perspectives from everybody," Rubenstein said. "One thing that's uniquely Brown about this project is that we have people from across campus working together with students and postdocs. And the students are being enriched by the dialogue—just seeing everyone think through an idea together. Every voice at that table is just as important as everybody else's. I find that really refreshing."

The team is hopeful that all its collective expertise will help lay the groundwork for an entirely new way of storing data.

Universe Explorers

Brown physicists are helping upgrade the world's most powerful particle accelerator.

BY NOEL RUBINTON '77

The Large Hadron Collider (LHC) in Switzerland, the world's largest and most powerful particle accelerator, is nearly 4,000 miles away from Providence, Rhode Island, but Brown faculty and students are immersed in research that is essential to the international project.

The giant collider near Geneva aims to unlock profound mysteries about the universe. It accelerates particles to near the speed of light before smashing them together, sending them flying at the Compact Muon Solenoid (CMS), one of the four large detectors at the LHC and the focus of Brown's research.

The goal of the CMS experiment is to investigate a wide range of physics phenomena, including extra dimensions and particles that could make up dark matter. The CMS represents a collaboration of about 4,000 particle physicists, engineers, computer scientists, technicians, and students from approximately 200 institutes and universities around the world.

"This is part of the age-old quest of humankind to understand where we come from and why we are here," said Brown physics professor Meenakshi Narain, one of the leaders of the CMS project, likening the experiments to "listening to the stories each particle has to tell and then unraveling the secrets of the universe."

Narain and two other Brown physics professors, Ulrich Heintz and Greg Landsberg, as well as other Brown postdocs, students, and technical staff are making preparations for the coming upgrade of the accelerator. Beam intensities will be amplified five times beyond the current level, and the amount of data transmitted will be significantly increased, so the shift requires parts of the CMS detector to be rebuilt in advance of the upgrade, scheduled for 2026.

Brown faculty and students are currently doing intensive research and testing in a fifth-floor lab of the University's Barus and Holley building, seeking the best way to make key new silicon tracking detectors for the upgraded accelerator. When the right design is perfected, production of 2,500 detector modules will begin. Narain, Heintz, and their team are receiving funds from the U.S. Department of Energy, with Brown positioned to receive up to about $10 million for work done between now and 2023.

"Building the detector is quite a technical and organizational challenge," Narain said. "The pieces we build have to be assembled with a precision better than the thickness of a human hair, and they have to fit together with parts that our colleagues are building in other institutes in the United States, Europe, and Asia. We have to coordinate with a global community."

Built around a huge magnet, the CMS equipment weighs more than 12,500 tons, or about the equivalent of 75 747-model jet planes, and is situated in an underground circular tunnel 17 miles in circumference.

The CMS detector functions as a giant high-speed camera, taking images of particle collisions from all directions millions of times each second. Information on particles is then assembled, like putting together puzzle pieces, so an image of the collision can be recreated for further analysis.

Narain has been an active participant in CMS experiments for many years and was elected in 2018 to chair the collaboration board of U.S. institutions in the CMS experiment.

"I'm honored that my colleagues from the 50 U.S. institutions that collaborate with the CMS Experiment have chosen me to represent them," Narain said. "I see this position as an opportunity to help U.S. CMS to become a more inclusive community and to enable all young scientists to contribute to their full potential to CMS and find rewarding career opportunities in academia and industry."

"This is part of the age-old quest… to understand where we come from and why we are here."
—Meenakshi Narain

She said of the collider and its experiments, "It's not only a scientific achievement, it's a tribute to humanity. It shows what we are capable of achieving when scientists and engineers from all over the world work together."

Narain is the first woman to chair the collaboration board, and she plans to work toward cultivating more diversity.

"With this comes the opportunity to promote women and other underrepresented minorities to have the opportunity to develop their careers to their fullest potential," she said. "I hope that I will be able to improve our community in the United States and in CMS in general to be more inclusive during my two-year term."

Narain and other Brown physicists working with the CMS experiment played key roles in the discovery in 2012 of the Higgs Boson, which at the time was the final missing piece in the Standard Model of particle physics that describes fundamental forces and classifies elementary particles. After the Higgs discovery, the CMS experiment has been searching for particles beyond the Standard Model, including a potential candidate particle for dark matter, which is thought to account for a majority of matter in the universe. ■

The world's largest particle accelerator, near Geneva, is being prepared for a major upgrade, including the detector being worked on at Brown.

MAXIMILIEN BRICE

BROWN RESEARCH INDEX

With more than 700 regular faculty and hundreds more in clinical and other categories, Brown produces an enormous range of research. The Brown Research Index captures some of this through faculty books published and selected faculty honors.

By the Book

In 2017, Brown professors published 81 books, spanning many disciplines and subjects.

American Studies

ELIZABETH HOOVER
- The River Is in Us: Fighting Toxics in a Mohawk Community

STEVEN LUBAR
- Inside the Lost Museum: Curating, Past and Present
- Museum History Journal, special issue on lost museums (*Editor*)

KIRI MILLER
- Playable Bodies: Dance Games and Intimate Media

Anthropology

MATTHEW GUTMANN
- Os significados de ser homem em uma Colonia Popular na Cidade do México

DANIEL SMITH
- To Be a Man Is Not a One-Day Job: Masculinity, Money, and Intimacy in Nigeria

Applied Mathematics

GEORGE KARNIADAKIS
- Numerical Methods for Stochastic Partial Differential Equations with White Noise

GOVIND MENON
- Mathematics and Materials (*Editor*)

BORIS ROZOVSKY
- Stochastic Partial Differential Equations

Archaeology

LAUREL BESTOCK
- Violence and Power in Ancient Egypt: Image and Ideology before the New Kingdom

FELIPE ROJAS SILVA
- Antiquarianisms: Contact, Conflict, Comparison (*Editor*)

Behavioral and Social Sciences

SARA BECKER
- Drug Addiction and Recovery (Vols. 1-13) (*Editor*)

Biology

KENNETH MILLER
- Miller & Levine Biology

Biostatistics

CONSTANTINE GATSONIS
- Methods in Comparative Effectiveness Research (*Editor*)
- Methods in Health Services Research (*Editor*)

Classics

JAMES FITZGERALD
- Special Issue on Locating Philosophy in the Mahābhārata, Journal of Indian Philosophy (*Editor*)

JOHANNA HANINK
- The Classical Debt: Greek Antiquity in an Era of Austerity

EFSTRATIOS PAPAIOANNOU
- Michael Psellos on Literature and Art: A Byzantine Perspective on Aesthetics (*Editor*)
- Christian Novels from the Menologion of Symeon Metaphrastes (*Editor, translator*)

Cognitive, Linguistic & Psychological Sciences

JAMES ANDERSON
- After Digital: Computation as Done by Brains and Machines

STEVEN SLOMAN
- The Knowledge Illusion: Why We Never Think Alone

Comparative Literature

ELIAS MUHANNA
- The World in a Book: Al-Nuwayri and the Islamic Encyclopedic Tradition

PETER SZENDY
- All Ears: The Aesthetics of Espionage
- Prêter l'oreille: Petite conférence sur l'écoute
- Le Supermarché du visible: Essai d'iconomie
- Lignes d'écoute, écoute en ligne (*Editor*)

Computer Science

ELIEZER UPFAL
- Probability and Computing: Randomization and Probabilistic Techniques in Algorithms and Data Analysis, Second Edition

East Asian Studies

HYE-SOOK WANG
- New TOPIK Master Final (*Translator*)

YANG WANG
- Basis Chinesisch Sprechen—Übungsbuch

Economics

ODED GALOR
- Unified Growth Theory (*Chinese edition*)

STELIOS MICHALOPOULOS
- The Long Economic and Political Shadow of History (*Editor*)

Egyptology and Assyriology

JAMES ALLEN
- A Grammar of the Ancient Egyptian Pyramid Texts, Vol. 1: Unis

JOHN STEELE
- Rising Time Schemes in Babylonian Astronomy
- Studies on the Ancient Exact Sciences in Honor of Lis Brack-Bernsen (*Editor*)

Engineering

BRIAN SHELDON
- Electro-Chemo-Mechanics of Solids (*Editor*)

English

OLAKUNLE GEORGE
- African Literature and Social Change

Epidemiology

DAVID SAVITZ
- Assessment of the Department of Veterans Affairs Airborne Hazards and Open Burn Pit Registry (*Editor*)

SIMIN LIU
- Journal for Diabetes, special issue (*Editor*)

German Studies

GERHARD RICHTER
- Imagens de Pensamento: Reflexões dos escritores da Escola de Frankfurt a partir da vida danificada

Hispanic Studies

JULIO ORTEGA
- Muestra del Nuevo Relato Mexicano

History

FAIZ AHMED
- Afghanistan Rising: Islamic Law and Statecraft between the Ottoman and British Empires

OMER BARTOV
- El ejército de Hitler: Soldados, nazis y guerra en el Tercer Reich

HAROLD COOK
- Ways of Making and Knowing: The Material Culture of Empirical Knowledge (*Editor*)

JENNIFER LAMBE
- Madhouse: Psychiatry and Politics in Cuban History

MARY GLUCK
- A láthatatlan zsidó Budapest

History of Art and Architecture
SHEILA BONDE
- L'abbaye Saint-Jean-des-Vignes, Soissons
- The Digital Middle Ages, special issue of Speculum (*Editor*)

ITOHAN OSAYIMWESE
- Colonialism and Modern Architecture in Germany

International Relations
ROSE MCDERMOTT
- Intelligence Success and Failure: The Human Factor

NINA TANNENWALD
- Do the Geneva Conventions Matter? (*Editor*)

Italian Studies
RONALD MARTINEZ
- Cleansing the Temple: Dante, Defender of the Church

Judaic Studies
DAVID JACOBSON
- The Charm of Wise Hesitancy: Talmudic Stories in Contemporary Israeli Culture

SAUL OLYAN
- Friendship in the Hebrew Bible

Literary Arts
SAWAKO NAKAYASU
- A TransPacific Poetics (*Editor*)

ELENI SIKELIANOS
- Make Yourself Happy
- Le tendre inventaire des vivants et des morts

MEREDITH STEINBACH
- The Enigma of Rain and Other Stories

COLE SWENSEN
- On Walking On
- Gave
- In the Beginning: Illustrated Stories from the Old Testament (*Translator*)

Mathematics
BRENDAN HASSETT
- Geometry over Non-closed Fields (*Editor*)
- Brauer Groups and Obstruction Problems—Moduli Spaces and Arithmetic (*Editor*)

RICHARD SCHWARTZ
- The Projective Heat Map

Medical Science
ERIC DARLING
- Articular Cartilage, Second Edition

HAMISH FRASER
- Global Health Informatics: Principles of eHealth and mHealth to Improve Quality of Care (*Editor*)

CHI-MING HAI
- Vascular Smooth Muscle: Structure and Function in Health and Disease (*Editor*)

AGNES KANE
- Some Nanomaterials and Some Fibres, Volume 111

Modern Culture and Media
BONNIE HONIG
- Public Things: Democracy in Disrepair

Obstetrics and Gynecology
MARGUERITE VIGLIANI
- A History of Medicine in 50 Discoveries

Philosophy
CHARLES LARMORE
- Das Selbst in seinem Verhältnis zu sich und zu anderen

Political Science
PETER ANDREAS
- Rebel Mother: My Childhood Chasing the Revolution

JULIET HOOKER
- Theorizing Race in the Americas: Douglass, Sarmiento, Du Bois, and Vasconcelos

WENDY SCHILLER
- Gateways to Democracy, An Introduction to American Government: The Essentials

DAVID SKARBEK
- The Decline and Rise of Institutions

MARGARET WEIR
- We the People, 11th Edition

Psychiatry and Human Behavior
KATHARINE PHILLIPS
- Body Dysmorphic Disorder: Advances in Research and Clinical Practice (*Editor*)

Public Policy
ERIC PATASHNIK
- Unhealthy Politics: The Battle over Evidence-Based Medicine

Religious Studies
STEPHEN BUSH
- William James on Democratic Individuality

SUSAN HARVEY
- Knowing Bodies, Passionate Souls: Sense Perceptions in Byzantium (*Editor*)

Theatre Arts and Performance Studies
SARAH DANGELO
- Native American New Play Festival: A Four Year Celebration—Second Edition (*Editor*)

PATRICIA YBARRA
- Latinx Theatre in the Times of Neoliberalism

Source: *Information from Faculty Activity Reports submitted to the Brown University Dean of the Faculty.*

Selected Faculty Research Honors

During the 2017—18 academic year, faculty won dozens of honors from national and international organizations.

ELI Y. ADASHI
Professor of Medical Science
- Honorary Doctorate, Faculty of Medicine, University of Ottawa

JASJIT AHLUWALIA
Professor of Behavioral and Social Sciences, Professor of Medicine
- Fellow, Society for Research on Nicotine and Tobacco

FAIZ AHMED
Associate Professor of History
- Fellow, American Research Institute in Istanbul, Turkey; National Endowment for the Humanities

EDWARD AKELMAN
Vincent Zecchino, MD, Professor of Orthopaedic Surgery
- A. Lee Osterman Excellence in Education Award, Society for Surgery of the Hand

NICOLE ALEXANDER-SCOTT
Associate Professor of Pediatrics; Associate Professor of Medicine; Associate Professor of Health Services, Policy, and Practice
- President-elect, Association of State and Territorial Health Officials

FRANCESCA BEAUDOIN
Associate Professor of Emergency Medicine
- 2017 Young Investigator Award, Society for Academic Emergency Medicine

ELIZABETH BENZ
Clinical Assistant Professor of Surgery
- Fellow, International College of Dentists

ROBERT BLAIR
Joukowsky Family Assistant Professor of Political Science and International and Public Affairs
- Henry Merritt Wriston Fellowship

DALE S. BOND
Associate Professor of Psychiatry and Human Behavior (Research)
- Innovation Award, Association of Migraine Disorders

DAVID BORTON
Assistant Professor of Engineering
- Director's Fellowship, Defense Advanced Research Projects Agency

B. ANTHONY BOGUES
Asa Messer Professor of Humanities and Critical Theory
- Presidential Faculty Award, Spring 2018

LUNDY BRAUN
Professor of Medical Science, Professor of Africana Studies
- 2018 Ludwik Fleck Prize, Society for Social Studies of Science

JOSEPH BRAUN
Associate Professor of Epidemiology
- 20 Pioneers under 40 in Environmental Public Health, The Collaborative on Health and the Environment

STUART BURROWS
Associate Professor of English
- 1921 Prize in American Literature, American Literary Society

ANDREW CAMPBELL
Dean of the Graduate School, Professor of Medical Science
- Fellow, American Society for Cell Biology

JOHN CAYLEY
Professor of Literary Arts
- The Marjorie C. Luesebrink Career Achievement Award, Electronic Literature Organization

MELODY CHAN
Assistant Professor of Mathematics
- Fellow, Alfred P. Sloan Foundation

SUZANNE COLBY
Professor of Psychiatry and Human Behavior (Research), Professor of Behavioral and Social Sciences (Research)
- President-elect, Society for Research on Nicotine and Tobacco

KAREEN COULOMBE
Assistant Professor of Engineering; Assistant Professor of Molecular Pharmacology, Physiology, and Biotechnology
- 2017 Rising Star Award, Cellular and Molecular Bioengineering Group of the Biomedical Engineering Society

DONALD COUSTAN
Professor Emeritus of Obstetrics and Gynecology
- Giant in Obstetrics and Gynecology, American Journal of Obstetrics and Gynecology

BROWN RESEARCH

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J.J. TREY CRISCO
Henry F. Lippitt Professor of Orthopedics, Professor of Engineering (Research)
■ Goel Award for Translational Research in Biomechanics, American Society of Biomechanics

JOHN CRONAN
Professor of Diagnostic Imaging
■ Pollack Medal, Society of Abdominal Radiology

SARAH DANGELO
Assistant Professor of Theatre Arts and Performance Studies
2017 Rhode Island Theater Award for Favorite College/University Production, Motif Magazine

AKILAH DULIN
Manning Assistant Professor of Behavioral and Social Sciences
Marie O. Weil Outstanding Scholarship Award, Association for Community Organization and Social Administration

JACK A. ELIAS
Senior Vice President for Health Affairs, Dean of Medicine and Biological Sciences, Frank L. Day Professor of Biology
■ Fellow, National Academy of Inventors

JENNIFER FRIEDMAN
Professor of Pediatrics, Professor of Epidemiology
■ Elected Member, American Society of Clinical Investigators

HUAJIAN GAO
Walter H. Annenberg Professor of Engineering
■ Theodore von Karman Medal, Engineering Mechanics Institute, American Society of Civil Engineers
■ Member, German National Academy of Sciences
■ Member, National Academy of Sciences

CONSTANTINE GATSONIS
Henry Ledyard Goddard University Professor of Biostatistics
■ Marvin Zelen Leadership Award in Statistical Science, Harvard T.H. Chan School of Public Health

SUSAN GERBI
George D. Eggleston Professor of Biochemistry, Professor of Biology
■ Fellow, American Society for Cell Biology

YAN GUO
Professor of Applied Mathematics; Chair, Division of Applied Mathematics
■ Elected Fellow, American Mathematical Society

CAROLINA HAASS-KOFFLER
Assistant Professor of Psychiatry and Human Behavior, Assistant Professor of Behavioral and Social Sciences
■ Dean's Award for Excellence in Research Collaboration in Public Health

MEREDITH HASTINGS
Associate Professor of Environment and Society and Earth, Environmental and Planetary Sciences
■ Special Award for the Earth Science Women's Network, American Meteorological Society

STEPHEN HELFAND
Professor of Biology
■ Fellow, American Association for the Advancement of Science
■ Fellow, Gerontological Society of America

PETER HEYWOOD
Professor of Biology
■ Fellow, Royal Society of Biology Council

STEPHEN D. HOUSTON
Dupee Family Professor of Social Science, Director of Early Cultures
■ Fellowship, American Council of Learned Societies
■ Jay I. Kislak Chair for the Study of the History and Cultures of the Early Americas, Library of Congress

AMANDA JAMIESON
Assistant Professor of Molecular Microbiology and Immunology
■ Director's Fellowship, Defense Advanced Research Projects Agency

JASMINE JOHNSON
Assistant Professor of Theatre Arts and Performance Studies
■ Postdoctoral Fellowship, Ford Foundation

GEORGE KARNIADAKIS
Charles Pitts Robinson and John Palmer Barstow Professor of Applied Mathematics
■ Research Award, Alexander von Humboldt Foundation

KARLA KAUN
Robert and Nancy Carney Assistant Professor of Neuroscience
■ 2018 Young Investigator Award, International Behavioural and Neural Genetics Society

ADRIENNE KEENE
Assistant Professor of American Studies
■ Spencer Postdoctoral Fellowship, National Academy of Education

GEORGE KONIDARIS
Assistant Professor of Computer Science
■ Director's Fellowship, Defense Advanced Research Projects Agency

MICHAEL KOSTERLITZ
Harrison E. Farnsworth Professor of Physics
■ Member, National Academy of Sciences

JESSACA LEINAWEAVER
Professor of Anthropology; Director, Center for Latin American and Caribbean Studies
■ Sawyer Seminar Grantee, Andrew W. Mellon Foundation

MITCHELL LEVY
Professor of Medicine
■ Member, Association of American Physicians

CAROL LEWIS
Professor of Pediatrics, Clinician Educator
■ Special Achievement Award for Distinguished Service and Dedication to the Mission and Goals, American Academy of Pediatrics

DIANE LIPSCOMBE
Thomas J. Watson Sr. Professor of Science; Director of the Robert and Nancy Carney Institute for Brain Science; Professor of Neuroscience
■ President-elect, Society for Neuroscience

LAURA LOPEZ-SANDERS
Assistant Professor of Sociology
■ Henry Merritt Wriston Fellowship

WANG LU
Assistant Professor of Music
■ Fellow, American Academy in Berlin

FELIPE MARTINEZ-PINZON
Assistant Professor of Hispanic Studies
■ Henry Merritt Wriston Fellowship

JENNIFER MERRILL
Assistant Professor of Behavioral and Social Sciences
■ 2018 Distinguished Scientific Early Career Contribution Award, Society of Addiction Psychology

KENNETH R. MILLER
Professor of Biology
■ President, Board of Directors, National Center for Science Education

ERIC NATHAN
Assistant Professor of Music Visiting Artist Residency, American Academy in Rome
■ Henry Merritt Wriston Fellowship

JAYANTI OWENS
Mary Tefft and John Hazen White Sr. Assistant Professor of International and Public Affairs and Sociology
■ Spencer Postdoctoral Fellowship, National Academy of Education

JOHN R. PARZIALE
Clinical Associate Professor of Orthopaedics
■ 2017 Distinguished Clinician, American Academy of Physical Medicine and Rehabilitation

MAUREEN PHIPPS
Chace-Joukowsky Professor of Obstetrics and Gynecology, Professor of Epidemiology, Assistant Dean for Teaching and Research on Women's Health
■ Accolades Award, American Congress of Obstetricians and Gynecologists

JILL PIPHER
Elisha Benjamin Andrews Professor of Mathematics, Vice President for Research
■ President-elect, American Mathematical Society

KAVITA RAMANAN
Professor of Applied Mathematics
■ Fellow, American Mathematical Society

CHARLES RARDIN
Professor of Obstetrics and Gynecology
■ President, American Urogynecologic Society

HOLLY SHAFFER
Assistant Professor of History of Art and Architecture
■ Postdoctoral Fellowship in History of Art, Smithsonian Institution

JESSE SHAPIRO
George S. and Nancy B. Parker Professor of Economics
■ Fellow, Econometric Society

ANITA SHUKLA
Assistant Professor of Engineering; Assistant Professor of Molecular Pharmacology, Physiology, and Biotechnology
■ Henry Merritt Wriston Fellowship

PRERNA SINGH
Mahatma Gandhi Assistant Professor of Political Science and International and Public Affairs
■ 2018 Andrew Carnegie Fellow, Carnegie Corporation of New York

SUZANNE STEWART-STEINBERG
Professor of Comparative Literature and Italian Studies
■ Guggenheim Fellowship, John Simon Guggenheim Memorial Foundation

ANTHONY SPIRITO
Professor of Psychiatry and Human Behavior
■ Dean's Award for Faculty Research Mentoring, Division of Biology and Medicine

SHARON SWARTZ
Professor of Biology; Professor of Engineering
■ Fellow, American Association for the Advancement of Science

STEFANIE TELLEX
Joukowsky Family Assistant Professor of Computer Science
■ Director's Fellowship, Defense Advanced Research Projects Agency

AMAL TRIVEDI
Associate Professor of Health Services, Policy, and Practice; Associate Professor of Medicine
■ Fulbright Senior Scholar Award, Australian-American Fulbright Commission

GREGORY TUCKER
Professor of Physics
■ WMAP Team Honoree, 2018 Breakthrough Prize in Fundamental Physics ■

Source: *Brown University Dean of the Faculty's Office, School of Public Health, Division of Biology and Medicine, as reported in the 2018 Commencement program.*

BROWN

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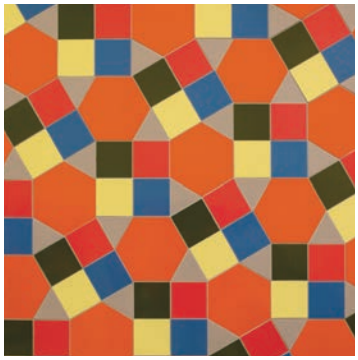

PUTTING IT TOGETHER:
Public art for Brown's new Engineering Research Center became itself a collaborative research project. Working closely with the School of Engineering, artist Spencer Finch created "The Garden in the Brain," nine artworks embodying concepts, such as tessellations, related to engineering. Above, handmade ceramic tile. Right, a glass wall separating Hazeltine Commons from the Teaching Lab includes a custom design that repeats three patterns across the band of windows.

WARREN JAGGER