SPRING 2022

CONVERGENCE

The magazine of engineering and the sciences at UC Santa Barbara

FOCUS ON: UNDERGRAD RESEARCH

THESE EXPERIENCES PRESENT PATHWAYS TO SUCCESS

BIG-BUCK BOTS

COMPETING TO IMPROVE "ALEXA"

TWO-PHOTON MICROSCOPY

A BETTER INSTRUMENT FOR VIEWING NEURAL ACTIVITY

THE SODIUM SOLUTION

SEEKING AN ALTERNATIVE TO LITHIUM-ION BATTERIES

CHAMPION OF ENGINEERING

DARRYL MCCALL GIVES BACK

UC SANTA BARBARA

MESSAGE FROM THE DEANS

TRESA POLLOCK
Interim Dean, College of Engineering; Alcoa Distinguished Professor of Materials

PIERRE WILTZIUS
Susan & Bruce Worster Dean of Science, College of Letters & Science

As this issue of *Convergence* went to press, spring quarter had started with most COVID restrictions lifted, providing a nearly complete return to normalcy and making this particular spring feel very much like the proverbial new beginning. We are immensely proud of, and grateful to, faculty, students, staff, and administrators across campus, who, over the past two years, have continually brought their best to the work of ensuring continuity under difficult circumstances.

For many in engineering and the sciences, responding to the pandemic meant redirecting or reprioritizing their research to save lives, through such work as developing new tests, mapping the genomes of new variants, modeling potential surges, and more. You'll meet some of those people on P. 36.

Research, of course, is integral to UCSB's mission as an R1 institution. And while the word quickly calls to mind faculty, graduate students, and post-docs working in labs, many *undergraduate* students also participate in laboratory research. In the "FOCUS ON:" section (P. 20), we highlight some of those students, the faculty who host them in their labs, the programs that support them, and the often life-changing experiences that result.

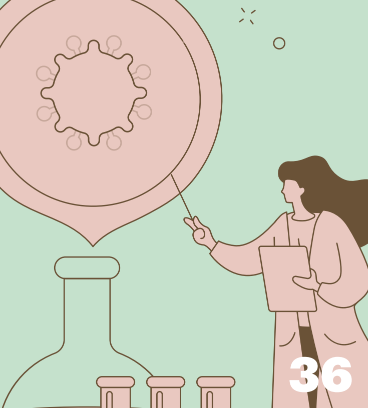
Elsewhere (P. 14), we tell you about a remarkable microscope built in the lab of **Spencer LaVere Smith,** an associate professor in the Electrical and Computer Engineering Department. In the "Tech Edge" section (P. 10), we visit the Microfluidics Lab, a multifaceted facility in Elings Hall that enables an array of experiments in multiple departments and disciplines. We also talk with its longtime, recently retired manager, **Dave Bothman,** who continues to work part-time doing what he loves.

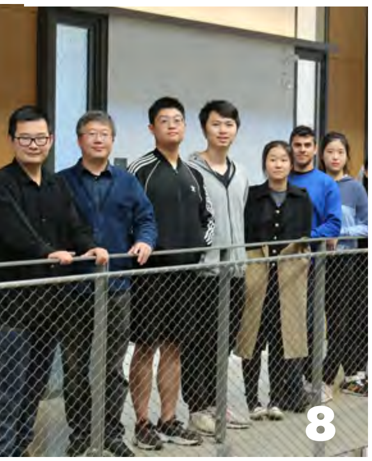
Lithium-ion batteries rule the portable power-supply world, but with the element becoming scarcer and more expensive, the search for alternatives is on. Materials assistant professor **Raphäele Clément** (P. 17) is pursuing pioneering NSF–funded research on a proposed sodium-ion battery.

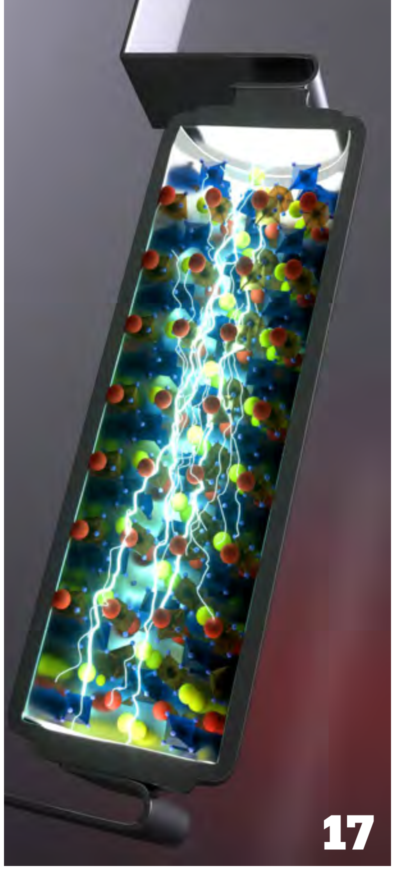
This issue also includes a pair of Q&A interviews, one (P. 34) with ChemE alumnus and major donor **Darryl McCall** (BS '78), and the other (P. 38) with Technology Management Department professor **Paul Leonardi,** who discusses his new book, in which he and his co-author present strategies companies can pursue to help them prosper in the digital era.

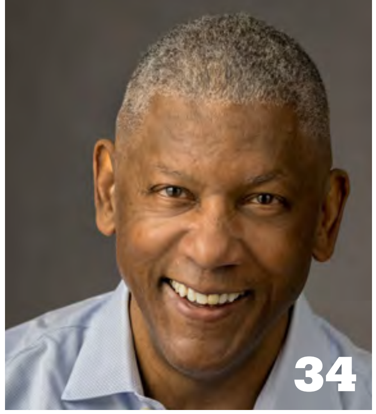
We have also included an inspiring article (P. 8) about two squads of computer science students who are among twenty teams in the world selected to participate in a pair of Amazon Challenges designed to expand the capabilities of Alexa devices.

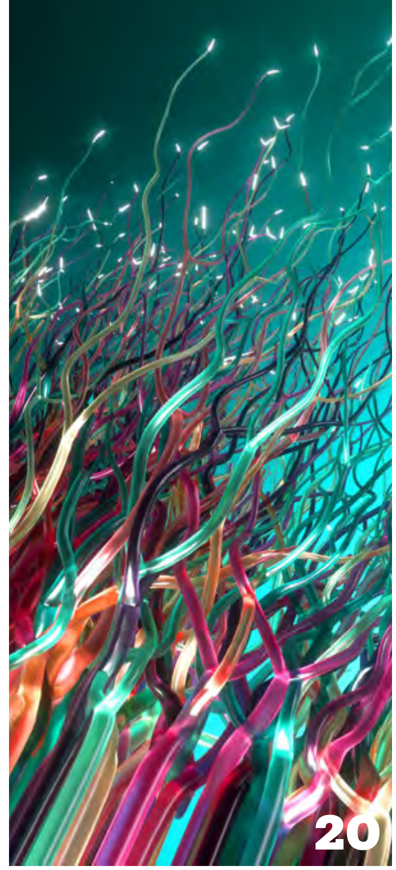
We hope you enjoy the issue and the rest of the academic year.











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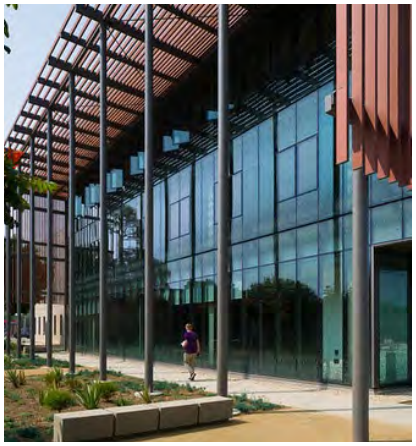
NEWS BRIEFS



Award-winning Henley Hall, seen from the south (left) and from the north.

HENLEY HALL: HONORS AND ACHIEVEMENTS

Henley Hall, which opened in 2020 as the home of the College of Engineering's Institute for Energy Efficiency (IEE), received some major honors in 2021, earning The American Architecture Award as well as LEED Platinum certification from the US Green Building Council, its highest rating for energy efficiency and sustainability.

Presented jointly by The Chicago Athenaeum: Museum of Architecture and Design, and The European Centre for Architecture Art Design and Urban Studies, the American Architecture Award honors the best in new and cutting-edge design in the U.S. and promotes American architecture and design here and abroad. The firm Kieran Timberlake designed the building, which has been recognized further by the American Institute of Architects (AIA), receiving awards from chapters in Santa Barbara, the city of Philadelphia, and the state of Pennsylvania. It also received an AIA Committee on the Environment Award of Excellence, which recognizes one project each year that demonstrates the highest level of commitment to sustainable design.

UCSB alumnus **Jeff Henley** and his wife, **Judy Henley,** an honorary alumna, sparked the donor-funded project with a $50 million gift to the College of Engineering in 2012. Silicon Valley–based alumna **Shawn Byers** and her husband, **Brook,** also made a significant contribution.

"Henley Hall is a reflection of UC Santa Barbara's commitment to energy efficiency, and our campus is thrilled that this state-of-the-art building has been nationally recognized for its innovative architectural design and superb sustainability," said **Chancellor Henry T. Yang.** "We are immensely grateful to donors Jeff and Judy Henley, and Shawn and Brook Byers for their tremendous vision and generosity in making Henley Hall — and these subsequent recognitions — a reality."

The 50,000-square-foot building, a model of efficiency that was constructed with more than twenty-percent recycled materials, includes passive features such as solar shading and a high-performance "skin," and active features that include demand-controlled ventilation and high-efficiency lighting modulated for occupancy and outdoor conditions. The building's extensive natural lighting, intelligent energy monitoring and control systems, and LED lighting yield a forty-percent energy savings over similar lab buildings.

Henley Hall is also a state-of-the-art research-and-learning facility, with both wet and dry labs, collaborative break-out spaces, conference rooms, a 124-seat lecture hall, and faculty and administrative offices. On the east side of the building, workspaces and offices have operable windows that stimulate airflow through an open, light-filled multistory atrium. On the west side, where labs are situated, air-monitoring and occupancy sensors reduce energy use for ventilation while protecting the safety of occupants and their research.

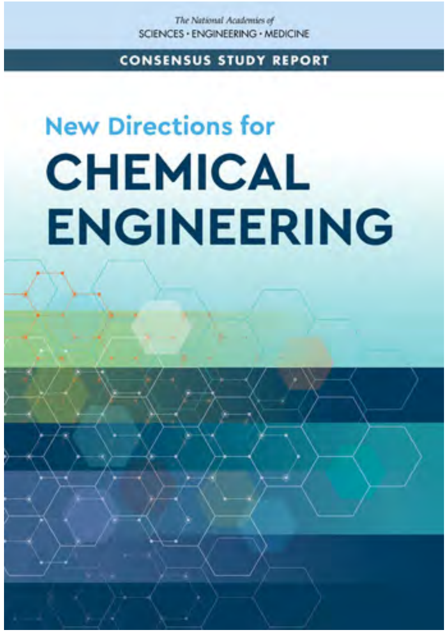
"We designed Henley Hall to be energy-efficient from the ground up," said **John Bowers,** IEE director and a professor of electrical and computer engineering. "It is great to have received such recognition for those efforts."

Bowers, the Fred Kavli Chair of Nanotechnology, describes Henley Hall as "a wonderful building to work in," adding, "The natural ventilation gives it a fresh, clean feel that we all love."

The ethos of the institute perfectly matched that of Kieran Timberlake. "We are honored to have worked with UC Santa Barbara to make Henley Hall the ideal home for the IEE," said Jason Smith, a partner at the firm. "Our expertise in innovative, sustainable design aligns with their forward-thinking mission to create new technologies in pursuit of an energy-efficient future."

"Energy efficiency is key to solving climate change and making U.S. industry more efficient in terms of energy use and expense," Bowers noted. "Henley Hall is essential to expanding UCSB's contributions in that important area."

WHICH WAY CHEM-E?



Rachel Segalman, the Schlinger Distinguished Professor and Department Chair of Chemical Engineering in the UC Santa Barbara College of Engineering, is one of seventeen members of an interdisciplinary committee (and one of two from UC campuses) that drafted an important new report mapping out the goals, challenges, and likely directions related to chemical engineering over the next ten to thirty years. "It will likely be pretty impactful in the discipline and beyond, similar to how the previous report, published more than thirty years ago, served as a roadmap for chemical engineers," said Segalman, who is also the Edward Noble Kramer Professor of Materials. "The work considers rapid advances in science and technology that have significantly changed the landscape of chemical engineering, ranging from computer modeling and machine learning to the growing focus on sustainability."

A preliminary web-based release of the 335-page report, titled *New Directions for Chemical Engineering (2022),* and published by the National Academies Press, a division of the National Academy of Sciences (NAS), went live on Feb. 9 on the NAS website. A public webinar was held on Feb. 28, and hard copies were released in March.

The purpose of the report, reads the preface, is "to articulate the status, challenges, and promising opportunities for chemical engineering in the United States, and benchmark its international stature, for the next ten to thirty years." Simply stated, the authors set out to answer the question: What is the future of chemical engineering?

In shaping that future, chemical engineers will need to grapple with what has already been done, including the creation of plastics and fluorinated chemicals, which, the authors write, "continue to cause unintended" environmental problems and give rise to greenhouse gasses that have put Earth's life-sustaining climate at significant peril. Further, they add, "Chemical engineers' ability to apply systems-level thinking from molecular to manufacturing scales uniquely positions them to address today's most pressing problems, including climate change and the overuse of resources by a growing population." The report suggests that chemical engineering is "well positioned as the enabling discipline in decarbonizing energy systems and materials without an impact on reliability and cost, while [remaining] cognizant of the existential threat of global climate change."

Chemical engineers, the report suggests, will lead in the work of engineering targeted, accessible solutions for human health, with impacts ranging from the development of personalized medicine, to applications of systems engineering in biology and health, to the production and end-of-life considerations of useful materials in a circular economy. In this and coming decades, chemical engineers will also increasingly apply new tools, such as machine learning and artificial intelligence, to solve complex problems.

The volume includes a global perspective, addressing, for instance, the need to invest in the U.S. research enterprise given China's large investments in technologies that are "either central or highly relevant to chemical engineering."

The report also details the kind of interdisciplinary, cross-sector collaborations that will be necessary to advance important societal goals, such as transitioning to a low-carbon energy system, ensuring sustainable production and use of food and water, developing medical advances and engineering solutions to support health equity, and manufacturing in ways that generate less waste and pollution.

New Directions contains a diversity-and-accessibilty component as well, calling for changes in chemical engineering education to ensure that the next generation of chemical engineers is more diverse and is equipped with the skills necessary to address the challenges ahead.

Glenn Fredrickson, the Mitsubishi Chemical Chair in Function Materials and professor of chemical engineering at UCSB, also provided input into the report.

KYLE LEWIS APPOINTED FELIPE CHAIR IN TECHNOLOGY MANAGEMENT

Kyle Lewis, chair of the Technology Management (TM) Department in the College of Engineering, has been appointed the Christian A. Felipe Chair in Technology Management. Felipe, a longtime investment-fund manager and angel investor, established the chair in 2014 with a $1 million endowment that also helped launch the Master of Technology Management (MTM) program. At the time, Felipe described the endowment as a great opportunity to create future entrepreneurs and technology leaders, and to recruit and retain top-notch faculty.

"I am pleased that Kyle Lewis has been honored with the Christian A. Felipe Chair in Technology Management," said Felipe. "She brings a wealth of research experience to the multidisciplinary field to explore the opportunities and challenges of ever-evolving technology."

Kyle Lewis

"It is an honor and a privilege to be appointed to the Christian A. Felipe Chair in Technology Management," said Lewis, who has been recognized previously as a recipient of the Jay Wright Forrester Award from the System Dynamics Society, as well as being named among the Top 50 Women in Business by the *Pacific Coast Business Times.* "Mr. Felipe's generosity has helped our department build an ecosystem for entrepreneurs in the Santa Barbara community, especially in the technology industry. We will continue to pursue that mission through leading-edge research and innovative teaching."

> **"KYLE LEWIS HAS BEEN A DRIVING FORCE BEHIND THE DEVELOPMENT, GROWTH, AND SUCCESS OF THE TM DEPARTMENT."**

Led by dedicated, award-winning faculty members who work in collaboration with industry partners, mentors, and lecturers, the Technology Management Department provides a unique business education that includes insights into both the theory and practice of forming and managing technology-driven enterprises.

Nearly two thousand undergraduate and graduate students participate annually in one or more of the academic programs offered by the TM Department, which include a PhD track in Technology Management, a Master of Technology Management, and UC–recognized undergraduate and graduate-level Certificates in Technology Management.

"Kyle Lewis has been a driving force behind the development, growth, and success of the Technology Management Department," said **Tresa Pollock**, interim dean of the College of Engineering and the Alcoa Distinguished Professor of Materials. "We congratulate her on this appointment, which is a well-deserved acknowledgement and recognition of her dedication as a chair, researcher, mentor, teacher, and colleague."

Lewis studies how organizations leverage individual and collective knowledge. She examines the performance of teams, especially those engaged in knowledge work such as professional services, new-product development, science and engineering, and project-based tasks. She has published articles in numerous top scholarly journals, served as a division chair in the Academy of Management, as senior editor for *Organization Science*, and as associate editor for *Management Science.* Prior to coming to UCSB in 2014, Lewis was a professor of management and faculty director of the Master of Science in Technology Commercialization (MSTC) program in the McCombs School of Business at the University of Texas at Austin.

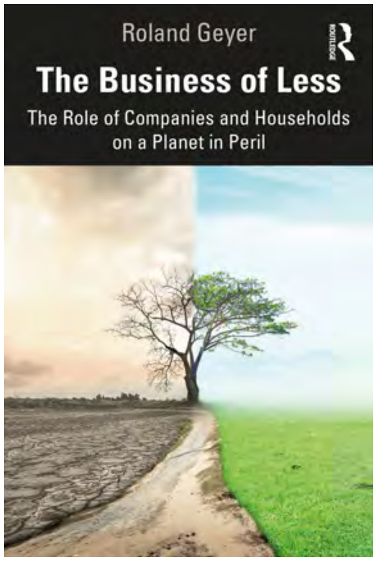
GETTING TO "NET GREEN"

Bren School professor of industrial ecology Roland Geyer

For the past roughly thirty years, ideas about corporate sustainability have tended to be synonymous with the pursuit of "eco-efficiency" and "win-win" opportunities, sometimes recast in the folksy phrase "doing well by doing good." It makes sustainability sound friendly and easy, and certainly something that can be achieved without much sacrifice.

Roland Geyer has an issue with that, and in his new book, *The Business of Less: The Role of Companies and Households on a Planet in Peril* (Routledge, 2022), the professor of industrial ecology at the Bren School of Environmental Science & Management casts a decidedly critical, highly expert eye on that feel-good notion of sustainability — the one, he says, "meant to assure us that companies can be protectors of the environment while also being profit maximizers."

An industrial ecologist with a background in physics, engineering, and economics, Geyer is an expert in life cycle assessment, the discipline that tracks the environmental impacts of products from resource extraction through manufacturing, transportation, useful life, and end of life. He has co-authored high-profile journal papers that quantified all of the plastic in the world's oceans and, later, all of the plastics ever made.



He has looked at the strategies for achieving important goals, such as cutting carbon emissions in the atmosphere and reducing plastics in the oceans, up, down, and inside out, and he finds them lacking. In *The Business of Less,* he introduces a new paradigm — "net green" — based on the idea that to reverse the alarming degradation of the planet we are currently witnessing will require businesses and consumers not just to improve the efficiency of their products, but actually to make and buy fewer of them.

That's right; Geyer proposes making, having, using, and throwing away less "stuff." He suggests, rather, placing a higher value on labor, the only input into products and services that has no environmental impact, and using that orientation to develop an economy that values labor over things. He lays out his case in a highly approachable book that is filled with anecdotes, evidence, examples, and clear language that spares the reader scientific jargon, acronyms, and unreadable "science" sentences.

CONNECTING THE MOLECULAR DOTS OF CANCER

Tumors are generally stiffer than the healthy tissue that surrounds them, and research shows that a stiffer tumor can contribute to the cancer's progression. But exactly how a stiff tumor affects a cancer cell's epigenome, the set of chemical modifications on a cell's DNA that regulate expression of genes, remains unknown.

Ryan Stowers, an assistant professor of mechanical engineering at UC Santa Barbara, has just been awarded a 2022 Young Investigator Grant (YIG) from the Breast Cancer Alliance (BCA). It was one of only five such awards given this year to support research aimed at identifying the biochemical pathway that drives the initiation and progression of cancer. The award provides early-career faculty with $125,000 in critical seed funding to generate the proof-of-concept evidence needed to apply for larger, longer-term grants, often with the National Institutes of Health (NIH).

"I am thrilled and honored to receive this grant, as only a handful of them are given out each year," said Stowers, adding that the two-year grant will fund a PhD student, research supplies, and fees to utilize shared facilities. "This funding will help support some of my lab's initial projects in the area of cancer mechanobiology, and the recognition it provides will help to establish us in the cancer-research community."

Broadly, mechanobiology is the study of how cells interface with and respond to their environment by changing how they appear and how they act.

Recently, the Stowers group demonstrated the first direct evidence that stiff environments can induce cancer-like behaviors through changes to the epigenome.

In his BCA-supported project, titled "Understanding Epigenomic Remodeling Inducted by Tumor Mechanical Properties," Stowers will investigate how the genome, the complete set of DNA in a cell, is reorganized in response to stiff environments. Epigenomic regulation, in part, enables the cell to express only certain genes, and not the entire DNA genome, a control mechanism that is disrupted in many cancers.

"In this research, we are trying to connect the molecular dots between the stiff environment outside of a cell and the altered gene expression and behavior of the cell itself, in order to identify a novel mode of cancer regulation," said Stowers, who joined UCSB's College of Engineering faculty in 2019 after earning his PhD in biomedical engineering from the University of Texas at Austin. "It has become increasingly clear that the stiff-tumor microenvironment can cause changes in cancer-cell behavior that exacerbate the disease."

Researchers in the Stowers lab create artificial tumor microenvironments by encapsulating cells in three-dimensional, mechanically tunable hydrogels. This allows them to more closely mimic the natural tumor environment, compared to culturing cells on flat, unnaturally hard petri dishes made of plastic or glass.

"We will use these hydrogels to precisely control the stiffness the cells are exposed to, and then evaluate the extent to which their epigenomes are remodeled," he explained. "Over the course of the two-year award, we will aim to identify the molecular pathway through which this stiffness sensing and signaling occur, and we will use high-throughput sequencing techniques to map out the changes we see."

Ryan Stowers received a Young Investigator Grant from the Breast Cancer Alliance.

> **“ THEIR FINDINGS COULD ALSO EXPLAIN WHY TUMOR CELLS DEMONSTRATE THE SO-CALLED MEMORY EFFECT, A PHENOMENON IN WHICH CANCER CELLS, AFTER BEING PRIMED BY A STIFF PRIMARY TUMOR, THEN INVADE THE SURROUNDING TISSUE AND MIGRATE AWAY FROM THE TUMOR. ”**

The team also plans to investigate how long the epigenomic changes induced by the tumor microenvironment persist. Their findings could also explain why tumor cells demonstrate the so-called *memory effect,* a phenomenon in which cancer cells, after being primed by a stiff primary tumor, then invade the surrounding tissue and migrate away from the tumor. Epigenomic memory imparted to the cells could explain why cells persistently invade during metastasis.

"This project is still very much about basic discovery and exploration," said Stowers. "However, if successful, we could uncover a new pathway that promotes breast cancer progression, which would provide targets for therapeutic intervention."

BIG-BUCK BOTS

Students seek to evolve AI to better serve humanity, while competing for millions of dollars

Many of us share our homes with a virtual task mate named Alexa, whom we routinely ask to tell us the time or the weather, to play a song, or to provide other useful, if mundane, small services. Now, two teams of students from the UC Santa Barbara Computer Science (CS) Department are competing in a pair of prestigious international competitions to help evolve the digital assistant's repertoire: the Alexa Prize TaskBot Challenge and SimBot Challenge.

Both are sponsored by Amazon and are outgrowths of the company's larger Socialbot Grand Challenge 4, which has the overarching goal of creating "an Alexa skill that converses coherently and engagingly with humans on popular topics and news events for twenty minutes, and achieves an average rating of at least 4.0 on a 5.0 scale," or, more simply put, "to make transformative advances in conversational AI."

William Wang, who leads the Natural Language Processing (NLP) lab at UCSB, is faculty advisor for the SimBot team, called GauchoAI, while fellow CS professor and NLP colleague **Xifeng Yan** advises the TaskBot team, named GauchoBot. "Our students are the team leaders, and they are driven by their interest and their passion," says Yan. "The PhD students wrote a proposal. William and I gave only some scientific suggestions and insights."

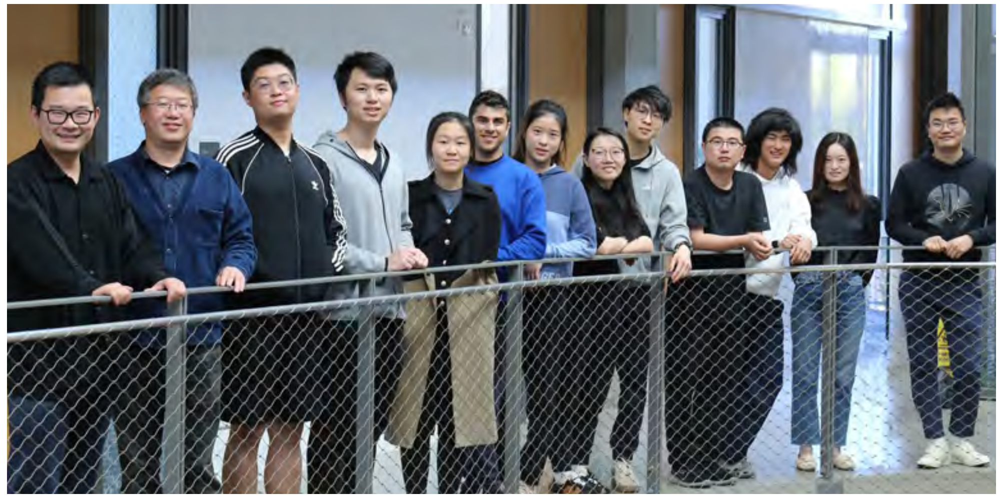
The Taskbot team includes computer science PhD students **Alon Albalak** (team leader), **Shiyang Li, Zekun Li, Jing Qian, Hong Wang, Yingrui Yang;** undergraduate CS majors **Qiru Hu** and **Carina Quan;** and undergraduate computer engineering major **Tom Zu.**

GauchoAI comprises CS PhD students **Jiachen Li** (team leader), **Tsu-Jui (Ray) Fu, Sharon Levy, Yujie Lu, Xinyi Wang, Wanrong Zhu,** and undergraduate CS major **Eddie Zhang.**

Just twenty teams from around the world were invited to participate — ten per challenge — with UCSB having a team in both. Two other teams in the SimBot Challenge are led by UCSB alumni. **Xin Wang,** who earned his PhD in William Wang's lab, leads the UC Santa Cruz team, and the team from The Ohio State University is led by **Yu Su,** who earned his PhD in Yan's lab. Finally, the TaskBot team from The Ohio State University is led by **Huan Sun,** who also earned her PhD in Yan's lab.

"It is a great honor to be accepted into these challenges," says Wang. "The groups selected to compete represent top programs in artificial intelligence [AI] all over the world. Being selected serves to recognize our years of efforts and achievements in the research areas of dialogue systems, conversational AI, and NLP in general, an area in which UCSB is consistently ranked as a top-ten national program. We are very excited about the opportunities that have been generously provided by Amazon Alexa."

TaskBot



Amazon TaskBot and SimBot teams (from left): William Wang, Xifeng Yan, Tsu-Jui Fu, Jiachen Li, Yujie Lu, Alon Albalak, Wanrong Zhu, Yingrui Yang, Zekun Li, Hong Wang, Eddie Zhang, Jing Qian, Shiyang Li

The Taskbot Challenge, which Amazon describes as "the first conversational AI challenge to incorporate multimodal (voice and vision) customer experiences," began in spring 2021 with the goal of "advancing the development of next-generation virtual assistants that will assist humans in completing real-world tasks that require multiple steps and decisions [i.e. following a recipe in the kitchen] by harnessing generalizable AI methodologies such as continuous learning, teachable AI, multimodal understanding, and reasoning.

The TaskBot Challenge will run for one year, with teams focusing on the domains of cooking and home improvement. The challenge incorporates multimodal customer experiences, so, in addition to receiving verbal instructions, customers who have Echo screen devices could also be presented with step-by-step instructions, images, or diagrams that enhance the guidance they receive for completing the task. For example, a user might ask Alexa how to fix a scratch on a car. The TaskBot will then ask the customer more questions about their task, and then interactively provide step-by-step instructions and explanations for each step, or potentially adjust its plan based on user input.

Ten teams successfully passed the certification process, meaning that real Alexa users could then have a conversation with TaskBots using Alexa-enabled devices. After an interaction ends, individual customers are asked to rate how helpful that TaskBot was with the task, and they have the option to provide freeform feedback. "Teams are using the feedback from real users to improve their bots," Yan explains. "Our team has successfully injected the newest AI models into our Taskbot for open-question answering. We were surprised by the high quality of the answers they delivered, especially in the situations where our system had to answer open questions that they had never seen before and for which they had not been prepared."

Success in the challenge requires participants to advance the state of the art in conversational AI and address difficult science challenges related to knowledge representation and inference, commonsense and causal reasoning, and language understanding and generation, among other challenges, requiring synthesis of multiple areas and approaches in AI.

After the certification process, an initial-skills-development period was held from last June through August. The competition began in September, finals will be held this May, and winners are to be announced in June. Each team received a $250,000 research grant to participate, as well as Alexa-enabled devices, free Amazon Web Services (AWS) cloud computing services to support their research and development efforts, access to the TaskBot Toolkit, data resources, and Alexa team support. The winning team in each challenge will receive an additional $500,000. The second- and third-place teams will receive an additional $100,000 and $50,000, respectively.

Regardless of whether a team wins its challenge, all participants retain ownership of their TaskBot, and Amazon will have a non-exclusive license to any technology or software the participants develop in connection with the competition. Publishing research papers as an outcome of the work on the Alexa Prize is required for all competing teams. "Society as a whole, including Amazon, can benefit from the open research that is linked to the competition," Wang says.

SimBot

The SimBot Challenge began in January 2022, and the initial skills-development period will begin this coming July, with winners to be announced in April 2023. The teams are focusing on "advancing the development of next-generation virtual assistants that will assist humans in completing real-world tasks by continuously learning, and gaining the ability to perform commonsense reasoning."

A key challenge for building intelligent robots is that they must be able to understand and manipulate everyday objects and know the way to a destination. For instance, it will be possible in the future to have a robot make you a cup of coffee, but the robot needs to understand how to navigate to the kitchen, get the coffee beans, grind them, and then pour hot water on them to make the coffee.

Wang and Yan describe how the teams in both challenges work: "We meet several times every week, and every two to three days, the team reviews all conversations that received low or high user ratings to understand why and to develop intelligent algorithms to further improve conversation quality and user engagement. You never know how a user might speak or what words they might use, so we have to think in advance about how they will reply and how to handle hundreds of different situations. Human beings have infinite ways to conduct their conversations. The team has to figure out the most general solution given a limited time window provided by the challenge. The process is quite stressful but one that we enjoy."

Dialogue systems, or so-called "conversational AI," which are foundational to building successful TaskBots and SimBots, are developing rapidly, creating many open research questions that need to be addressed, say Wang and Yan. "While it is possible that one of our students might have the luck to develop a brilliant idea during the contest, we think of it as more of an educational opportunity provided by Amazon that allows student to put state-of-the-art AI techniques into real use and observe their performance by receiving rapid feedback from actual users."

"Truthfully, many of the bots do not work well out of the box," Wang says. "This experience will help us identify truly valuable research problems that we can work on after the competition. Our research goal is aligned with Amazon's goal for Alexa: to make interacting with conversational bots as natural as interacting with another human being. There is a long way to go."

TECH EDGE

The Microfluidics Lab: Enabler of Experimentation

The Microfluidics Lab (MFL) at UC Santa Barbara is one of the few campus labs where relatively little research is conducted. It is, rather, an *enabling* lab, where researchers and lab staff fabricate tools required for their experiments. Established in its current location in Elings Hall ten years ago, the lab began life closely aligned with semiconductor research, according to longtime manager, **Dave Bothman,** who has spent 36 years at UCSB and who, though officially retired, continues to work part-time in the MFL, which gets its name from the word for the easily *described* process of microfluidics, which Bothman says, is "simply making devices that have really small channels for fluids to flow through."

The Microfluidics Lab came to be in a rather roundabout way. UCSB has a long history of semiconductor manufacturing, and in the late 1990s and early 2000s, Bothman explains, that work expanded into making microelectromechanical systems (MEMS), which are mechanical devices made with the same tools developed to manufacture semiconductors. "Eventually, some of those MEMS researchers started moving into microfluidics," explains Bothman, who began his career as a professional "tinkerer" while working in a machine shop as a UC Santa Cruz undergraduate. He then transferred to Scripps Institute, where he spent seven years building experiments and equipment for ocean research. He was hired by the Department of Mechanical Engineering at UCSB in 1986. "I feel really grateful that I've been able to advance my career and continue to work with my hands," he says.

Bothman's successor as MFL manager, **Brian Dincau,** says that he looks forward to "playing a key role in the future development of the lab and training students to make experimental devices similar to what I've made for my own research. I'm excited to support other research groups that have an idea of what they want to measure or what sort of experiment they want to run but might not yet know how to build what they need."

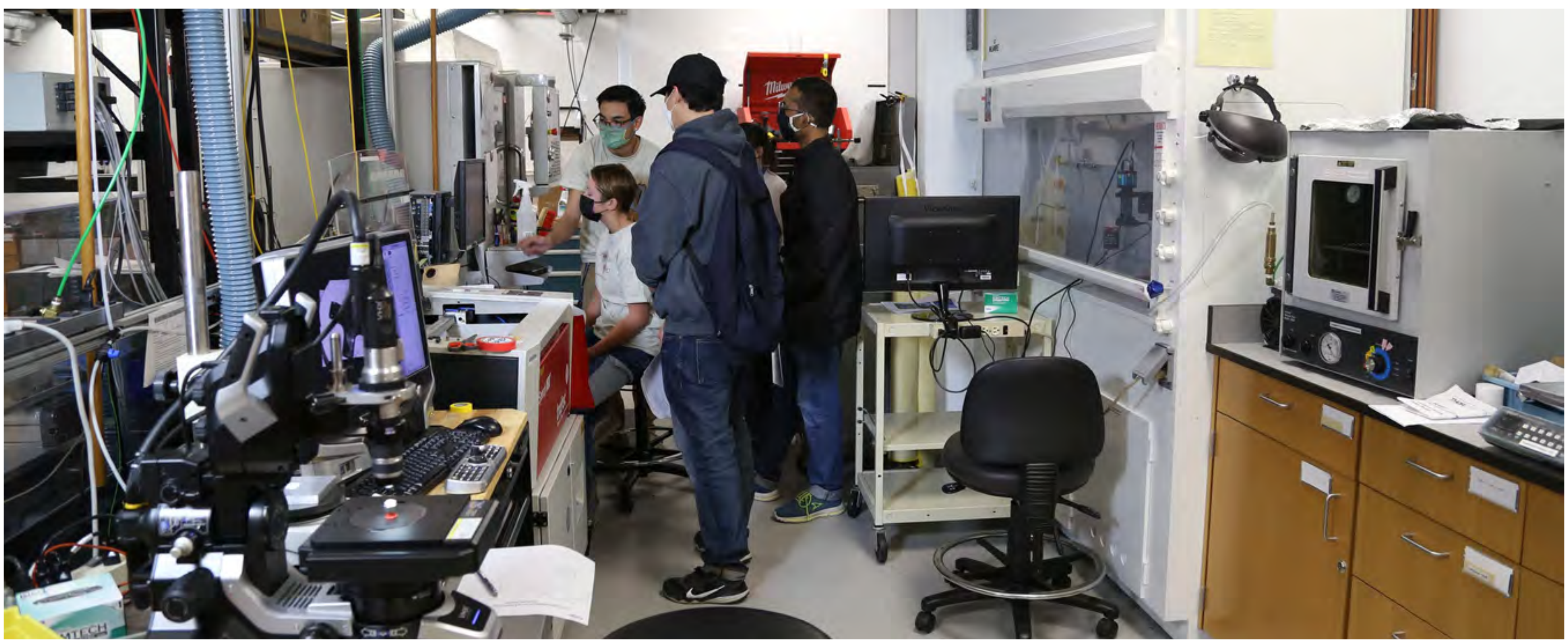
He also says that he and his predecessor have a lot of similarities: "We both like to tinker, we both like to talk about relatively technical things, and we both really value the duality of the lab — that it serves the university's dual goals of furthering research by helping people to invent and create, while providing students with a world-class training and learning environment. I think education is one of the most important means of enacting change for the good, and I really want to be a part of that."

In the early days of microfluidics, Bothman says, everyone who was making them was a cleanroom user, but a cleanroom is not an easy lab to get started in. There is a start-up fee, and it takes about six months to learn to use all the tools and work in it safely. No undergraduates are allowed in, and graduate students have to take a prerequisite class before entering. Most microfluidics work, however, either does not require a cleanroom or requires it for only a small part of the process.

Eventually, with researchers from other departments finding uses for MF devices, an informal word-of-mouth supply process developed that made it possible for interested researchers to obtain a device they needed from someone who had access to a cleanroom — but in nothing that could be considered a timely manner.

Recognizing the bottleneck, Bothman suggested to administrators in the California NanoSystems Institute (CNSI) at UCSB that they build an MF lab in Elings Hall. "They had already been thinking about that and were enthusiastic, and so we built this lab," Bothman says. "The intention from the very beginning was that users from all over campus could come and make MF devices."

That intention was sound, as the process of moving fluids through very small channels, which can range in diameter from about seventy microns (the approximate width of a human hair), up to about one millimeter and even, occasionally, larger, is called for



Students undergo training on the various equipment and instruments in the Microfluidics Lab. The Keyence VHX 5000 microscope is in the left foreground.

in widely varied research and an array of disciplines. In fact, before COVID, the lab had about two hundred users, and in mid-pandemic, in 2021, people from more than forty different research groups used it. It attracts everyone from physicists who might be studying the physics of droplet formation to chemists who might want to mix reagents in extremely small volumes," Bothman says.

Mechanical engineering professor and CNSI co-director **Megan Valentine,** who is co-director of the California NanoSystems Institute, which supports and houses the Microfluidics Laboratory, says that the MFL "has been a tremendous resource for a number of projects in my experimental research group; everyone in my group uses this facility, from undergrads just starting on their first project to seasoned researchers who are independently driving multiple projects. Dave Bothman has provided important training and oversight, while encouraging researchers to explore new designs and test new ideas."

Valentine says that researchers in her group have often used the lab's 3D printing capabilities to generate low-cost, customized devices that can apply rapid forces to cells during imaging, as well as microfluidic devices capable of rapid fluidic mixing or generation of microscale droplets. "These devices are then used to understand and control the mechanical properties of cells in order to create improved diagnostics and therapeutics," she says. "The tools and guidance provided by the MFL were essential for this work."

Emilie Dressaire, an assistant professor in mechanical engineering whose research is aimed at developing bio-inspired strategies to control and sense fluid flows at small scales — work that combines fluid dynamics, soft matter, and biology — says that her group uses the lab to make MF devices, which are then used to make emulsions and droplets. "We're hoping to use those emulsions to stabilize structures," she says, adding, "We've been using all the lab's PDMS tools [PDMS, or polydimethyl siloxane, being the most widely used silicon-based organic polymer]. We use the 3D printer to make molds, and we use the molds to create surfaces having a "hairlike" texture similar to that of cilia."

Paul J. Atzberger, a professor in Mechanical Engineering and Mathematics, has made use of the MFL for multiple collaborative interdisciplinary projects. They have involved modeling particle and polymer transport phenomena within fluidic devices, and related experiments; developing novel approaches for modeling and simulating transport phenomena associated with device electrostatics and electrokinetics; and investigating the roles of phenomena such as discrete ion-ion correlation effects in transport within microfluidic devices.

One of the ways people most frequently use the lab is to make what are called *droplet generation chips.* And, Bothman explains, one of the most common ways to make the chips is to cast liquid silicon onto a silicon wafer that has some raised sections, creating a liquid silicon cast on top of a mold. Peeling the mold off leaves channels embossed onto the silicon. That piece of silicon can then be bonded to a glass slide that has inlets and outlets, or has holes punched in it to serve as inlets and outlets, and can then be put under a microscope so that the flow can be observed.

Not all chips made in the lab are used for generating droplets. Some are employed to breed bacteria, while others are intended to encapsulate bacteria inside a droplet of nutrient so that the bacteria can be observed as it evolves on the chip. Still other chips are applied in processes that use electro-chemistry to detect disease.

In addition to the many and varied researchers who fabricate devices in the lab, another group of people come to use a unique microscope — the Keyence VHX 5000 — which, Bothman says, "can do things that no other microscope on campus can."

While many other microscopes

> "This scope has a function that allows it to provide perfect focus across a much greater depth of field, ranging from ten times to a thousand times resolution."

Longtime, recently retired Microfluidics Laboratory manager, Dave Bothman (left) and his successor, Brian Dincau, who says he shares Bothman's "fondness for tinkering."

can magnify up to a thousand times, as the VHX 5000 can, that level of resolution typically yields a very shallow depth of field. But this scope has a function that allows it to take multiple scans and combine them to provide perfect focus across a much greater depth of field, ranging from ten times to a thousand times resolution. "It also takes really good photos and has excellent measuring capabilities," Bothman says.

For her doctoral work, which built upon a decade-long chain of research at UCSB, **Marcela Areyano** (PhD '21) used the microscope to measure the diameter of the elastic threads that enable mussels to adhere to wet surfaces. Areyano's measurements allowed her, in turn, to calculate the area of the threads and get meaningful measurements of their mechanical properties. "Any chance I got, I tried to use that microscope," she says.

Areyano also made equipment in the lab for testing research setups to look at how mechanics and physical structures affect the performance of millimeter-scale synthetic adhesive structures modeled after adhesive mussel strings. For that, she laser-etched marker guides onto glass slides to ensure that her samples would be correctly placed and her readings, therefore, consistent; used the 3D printer to make molds to form the structures, and used the lab's ovens to cure the resulting synthetic structures, which resembled mussel threads.

Many tasks, many tools, one busy place, and a microscope that is powerful but, more importantly, versatile: fitting for the diversely empowering Microfluidics Lab.

World of Wizards: Dave Bothman (right) and the four undergraduate Workshop Wizards, who keep the lab running (from left) Vedad Bassari, Jeran Bruce, Eliana Petreikis, Andrew Furst.

YOUNG WIZARDS of the MFL

In 2020, to address lab-access challenges presented by COVID, Microfluidics Lab (MFL) manager, **Dave Bothman,** began training a group of undergraduate engineering students he called the Workshop Wizards, to train lab users on equipment and do maintenance in the lab. "At that time, the height of the pandemic, a lot of people couldn't come to the lab, so they would send designs of what they wanted to build, and the Wizards would build it and leave it outside for them to pick up," Bothman says, adding, "The goal was to hire first- and second-year students with the expectation that when they became seniors, they would be working in campus research labs but still be available to train younger Wizards. Learning to use all the tools here and in the Innovation Lab [down the hall] would position them well to get good research internships and jobs."

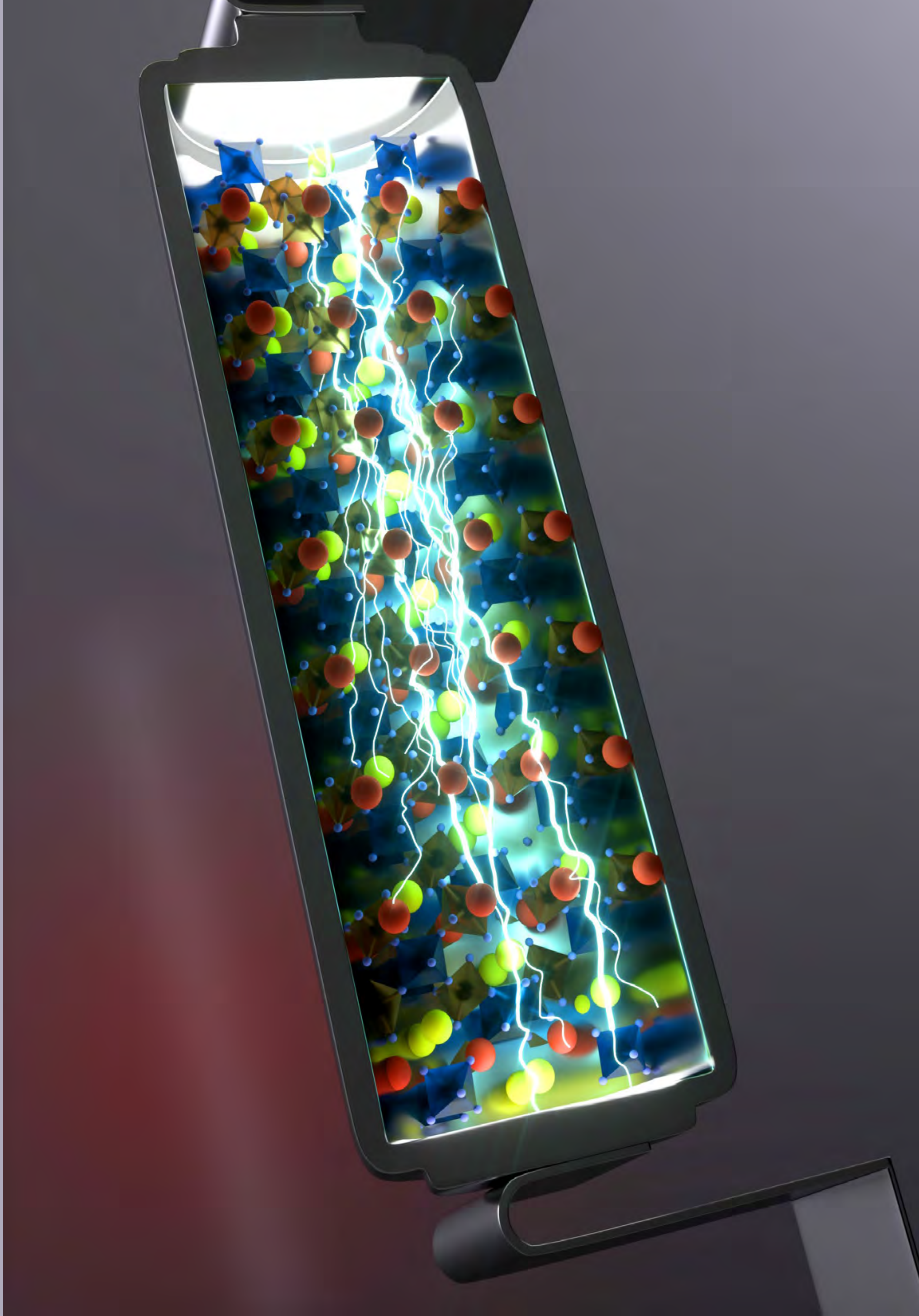
One of the lead Wizards is third-year undergraduate mechanical engineering major **Andrew Furst,** who says, "I love working on projects, working with my hands, trouble shooting, and coming up with solutions to problems. Working here, I get to interact with so many other researchers from so many different labs and fields of study, and they all involve engineering in some form and using the same resources for so many different purposes.

"Going from concept and design to a physical product and seeing it fit into their experiment, and then looking at their research paper and knowing that we had a small part in that is what I love most about it."

Furst's wizarding duties get him involved with other labs around campus, and even across the country, making precision lab instruments, devices, and apparatuses that are not available off the shelf.

One recent project involved fabricating a nasal stent for a rhinoceros on the East Coast, to address a buildup of scar tissue in the animal's nasal cavity, which had resulted from an infected tooth and had required several surgeries a year to remove. All four of the Workshop Wizards were involved in the process, which Furst describes as "communicating back and forth, figuring out which materials were bio-compatible, drafting different designs, coming up with different ways to produce the stent, and making it."

"The Wizards is a great program, and one that we would like to expand," Bothman says. "Over the years, many groups on campus outside of engineering have really benefited from having engineers help in their labs. They bring a different perspective and skillset than the students in psychology or biology, and it works out great for everybody to work together."



Concept illustration of ions and electrons migrating in a sodium-ion battery. Raphaële Clément seeks to develop the battery and improve the "suitability of nuclear magnetic resonance for looking at more complex systems."

the SODIUM SOLUTION

Raphaële Clément pursues a novel alternative to lithium-ion batteries

Raphaële Clément aims to develop a sodium-ion battery and new NMR techniques.

Lithium (Li) is the active ingredient in rechargeable batteries that power today's smart phones, laptops, and electric vehicles, but lithium's increasing scarcity and associated high price have led researchers to search for other, more abundant elements to replace it. Many researchers have turned to sodium (Na), which is below lithium in the periodic table and, accordingly, shares many of its properties. Sodium is also nearly 1,200 times more available in the world than lithium, making it far more affordable to extract and purify.

The deployment of sodium-ion batteries, which function through shuttling of sodium ions and electrons back and forth between the battery's electrodes upon charge and discharge, has been hampered by a lack of cathode materials that are capable of storing large amounts of charge reversibly, that is, taking up sodium ions and electrons during discharge of the battery and releasing them, so that they can be returned to the anode material, as the battery is recharged.

"Viable sodium alternatives to current lithium-based batteries have proven elusive, partly because a limited number of sodium-ion cathode materials have been tested to date," says **Raphaële Clément,** an assistant professor in UC Santa Barbara's Materials Department. She recently received an Early CAREER Award, the most prestigious prize given by the National Science Foundation (NSF) to support early-career faculty, providing her lab with more than $700,000 over five years to pursue research and educational activities related to developing a sodium-ion battery.

To find the missing cathode materials, Clément, who joined the UCSB Materials Department in 2018 after earning her PhD in chemistry from the University of Cambridge, proposes to study a new class of *transition metal fluorides* that hold promise for use in high-energy-density sodium-ion cathodes. These compounds — derivatives of Na_2MgAlF_7, a mineral known as *weberite* and named after the nineteenth-century Danish merchant who discovered it — radically depart from systems that have been explored previously for lithium. Clément will focus her search on weberite-like materials containing Earth-abundant elements, including fluorine, sodium, magnesium, aluminum, manganese, and iron.

As part of the project, titled "High-Resolution NMR for Paramagnetic Sodium Electrodes," researchers in Clément's lab will explore the new materials at a fundamental level, seeking to understand the links between their chemistry, atomic structure, and electrochemical performance. They plan to achieve this by using nuclear magnetic resonance (NMR) spectroscopy, a powerful technique that makes it possible to analyze the atomic structure of a material by tracking interactions between nuclear and electronic *spins* — tiny bar magnets associated with atomic nuclei and electrons — when the material is placed in a powerful magnetic field. NMR allows scientists to study the charge-discharge processes in battery materials.

"When a battery is operating, you have two materials [one in the anode and the other in the cathode] that can store sodium ions. On discharge, sodium ions are extracted from the anode material and then travel through a liquid electrolyte to be inserted into the cathode material. The opposite happens when charging the battery," Clément says. "When you extract a sodium ion from the anode, you're extracting a positive ion, so you also have to extract an electron at the same time from that material to make its charge neutral and, therefore, stable. That electron has to come from another metal in the material itself.

"The particular mineral we're starting from, Na_2MgAlF_7, does not contain any of what we call *redox active* transition metals, which actively give up electrons," she adds. "Na_2MgAlF_7 contains magnesium and aluminum, neither of which will give up an electron. So, we need to alter the chemistry of the weberite mineral and substitute magnesium and/or aluminum with a transition metal that *will* give up an electron. Manganese and iron are the metals we're interested in that will do that."

An initial obstacle to the research is that the compound Clément has chosen is difficult to make. Normally, she explains, "You would start with reagents in powder form and heat them to high temperatures, around one thousand degrees Celsius, and then cool them to form crystals. But these materials are very hard to make in that way, so we are using what's called *mechanochemical synthesis.* Basically, you place the powdered reagents in a metal jar, add metal spheres, and shake the jar at a very high speed for a couple of days to a week, inducing a chemical reaction between the reagent powders."

The process, however, yields a material that is not very crystalline, so, Clément says, "Typically, you use a quick annealing step in which you compress the powder into a pellet and then heat it in a furnace for a half hour to a few hours, to around five hundred degrees, and then cool it to get a more crystalline material."

There are good reasons why lithium, and not sodium, became the go-to element in the battery industry, Clément says: "Lithium is a smaller ion than sodium, so it is typically easier to insert and extract from materials [with a concurrent electron flow], which is why lithium-ion batteries work so well. It is also lighter than sodium, providing good energy density and making batteries lighter.

Finally, lithium metal has a lower voltage than sodium metal. This is important because in batteries you have to maximize the *potential difference* [in voltage] between the anode and cathode materials, because the energy density of a battery is equal to the potential difference between the two electrodes *times* the amount of charge that can be stored in these electrode materials. "So, if you maximize the potential difference and/or the charge storage capacity, you increase the energy density of your battery, and typically, lithium offers a greater potential difference than sodium does," Clément says. "Overall, sodium can work as well as lithium, but it's tricky to find the right materials that will reversibly allow the insertion and extraction of sodium from the crystal structure. That's what we are looking at with these materials.

> While these are some of the more exciting cathode materials out there, they're difficult to make and a not well understood, having been studied hardly at all for battery applications.

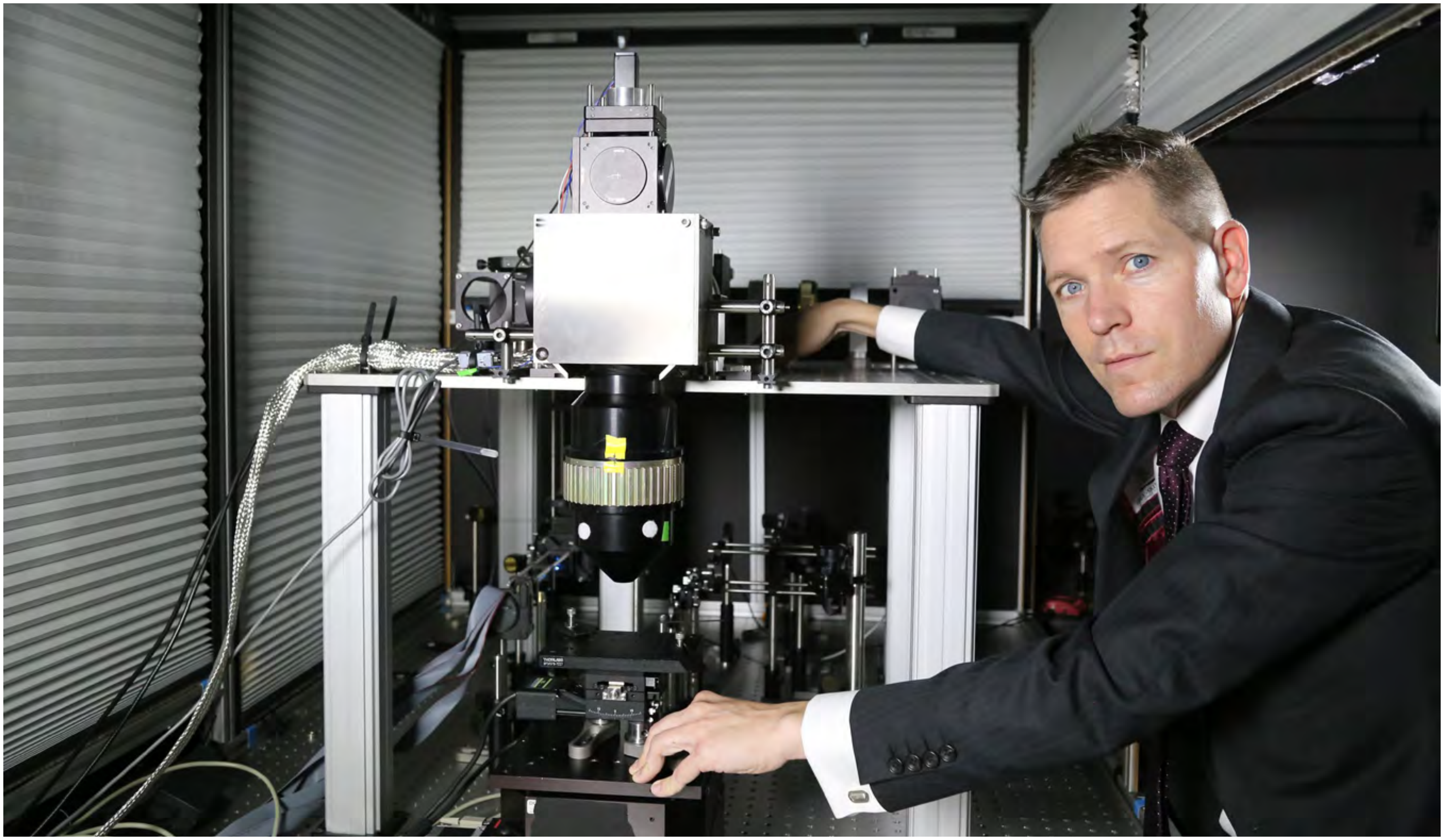
"We're interested in these materials, because they have an open crystal structure that may allow them to hold a lot of sodium," she continues. "They also contain fluorine, which is important in this composition, because it typically leads to high sodium insertion and extraction voltages. That would make the working potential of the cathode quite high, which is good, because then you can improve the energy density of your sodium-ion battery."

Clément describes the research as "highly exploratory," because, she says, "While these are some of the more exciting cathode materials out there, they're very difficult to make and are not well understood, having been studied hardly at all for battery applications. We're first going to make some of the proposed materials, determine their atomic structure and their behavior as cathode materials, and then optimize their chemical composition to improve their performance."

Another important part of her CAREER Award–funded research, Clément says, is "pushing the boundary of the NMR technique [her area of expertise] that we use to study the materials. We plan to establish a novel NMR method to gain atomic-level insights into the working principles of these battery electrodes. We can then use that understanding to design new materials and chemistries having enhanced properties."

Using NMR to study the cathode materials of interest to this work can be challenging, because the redox active transition metals, such as the manganese and iron being investigated here, contain unpaired electrons (the very electrons that are released or taken up by the electrodes during charge-discharge). "You have many of these electrons coming from the manganese and iron atoms in your cathode, so you'll have a lot of interactions between spins, leading to very broad NMR spectra," she says. "NMR provides a lot of information on the structure of these materials, but because the spectra are so broad, the data can be difficult to interpret. The new technique that we're developing will allow us to simulate the NMR properties of complex systems, like the weberite cathodes of interest to us, in a more accurate and, more importantly, a more efficient manner. In broad terms, we are looking at developing not just materials, but ways to improve the suitability of NMR for looking at more complex systems."

Clément is one of eleven junior faculty from the COE who have received a CAREER award since April 2020. UCSB ranked first among public universities in the percentage of eligible-junior faculty who received the awards from 2016-'21.



Spencer Smith makes adjustments to the instrument he built, which enables him to rapidly, and simultaneously, image neural activity in multiple areas of a brain.

Using Two Photons (Instead of One) for a Better View of Brains

Spencer Smith builds a new microscope for imaging widely distributed neural circuitry

Advancing our understanding of the human brain requires new insights into how neural circuitry works in mammals, including laboratory mice. These investigations require monitoring brain activity with a microscope that provides resolution high enough to see individual neurons and their neighbors.

Two-photon (2p) fluorescence microscopy has significantly advanced researchers' ability to do that, and the lab of **Spencer LaVere Smith,** an associate professor in the Department of Electrical and Computer Engineering at UC Santa Barbara, is a hub of research related to advancing the technology. As the principal investigator on the five-year, $9 million NSF–funded Next Generation Multiphoton Neuroimaging Consortium (NEMONIC) hub, which was born of President Obama's BRAIN Initiative and is headquartered at UCSB, Smith says he is working, "to push the frontiers of multi-photon microscopy for neuroscience research."

Last fall, in *Nature Communications,* Smith and his co-authors reported the development of a new microscope they describe as

With normal imaging, you see only the very top of the brain. Two-photon imaging allows us to image deeper down and still attain sub-cellular resolution.

"Dual Independent Enhanced Scan Engines for Large field-of-view Two-Photon imaging (Diesel2p)." This new two-photon microscope provides unprecedented brain-imaging ability. It also has the largest field of view (up to 25 mm^2) of any such instrument, allowing it to provide subcellular resolution of multiple areas of the brain in one shot.

"We're optimizing for three things: resolution, to see individual neurons; field of view, to capture multiple brain regions simultaneously; and imaging speed, to capture changes in neuron activity during behavior," Smith explains. "The events that we're interested in imaging last less than a second, so we don't have time to move the microscope; we have to get everything in one shot, while still making sure that the optics can focus ultrafast pulses of laser light."

The powerful lasers that drive 2p imaging systems, each costing about $250,000, deliver ultrafast, ultra-intense pulses of light, each pulse being more than a billion times brighter than sunlight and lasting 0.0001 nanosecond. A single beam, with 80 million pulses per second, is split into two wholly independent scan engine arms, so that the microscope can scan two regions simultaneously, with each configured to different imaging parameters.

In previous iterations of Smith's instrument, the two lasers were yoked and configured to the same parameters, an arrangement that strongly constrains sampling. Optimal scan parameters, such as frame rate and scan region size, vary across distributed neural circuitry and experimental requirements. The new instrument allows for different scan parameters to be used for each of the two beams. Also incorporating custom-designed and custom-manufactured elements, including the optical relays, the scan lens, the tube lens, and the objective lens, the new instrument is already being adopted widely for its ability to provide high-speed imaging of neural activity in widely scattered regions of the brain.

Two-photon microscopy is a specialized type of fluorescence microscopy (FM). To perform such work in Smith's lab, researchers genetically engineer mice so that their neurons contain a fluorescent indicator of neuron activity. The indicator was made by combining a fluorescent protein from jellyfish and a calcium-binding protein that exists in nature. The approach leverages the fact that a neuron experiences a brief, orders-of-magnitude increase in calcium when firing. When the laser is pointed at the neuron, and the neuron is firing, calcium comes in, the protein finds the calcium and, ultimately, fluoresces.

In normal FM, a blue light or other short-wavelength light is used to excite the dye, because it has enough energy to raise the target molecule from its normal ground state to its excited state. When the molecule returns to its ground state, fluorescent light is emitted back to the optical system, at which point the image is captured.

The problem with this technique is that the light used to excite the sample has a short wavelength, and short-wavelength light is scattered strongly by brain tissue. Moreover, this light enters the specimen in the shape of a cone, which narrows to the point of focus and expands back out into a cone beyond the focal point. All of the light that is not at the narrowest point is out of focus and shows up as a blurry object or as background superimposed onto the sharply focused region. The fact that fluorescent light is emitted from the entire illuminated cone of the sample, not just from the focus area, is a general problem for fluorescence microscopy.

Two-photon imaging enhances FM by leveraging the quantum behavior of photons and molecules in a way that prevents the generation of a considerable amount of out-of-focus fluorescent light. Whereas normal FM requires only a single high-energy, short wavelength light (e.g., blue), two-photon microscopy uses two lower-energy, longer wavelength (e.g., infrared) photons to do the same thing.

The idea for infrared 2p microscopy is to cause two infrared photons, each having half the energy of a blue photon, to arrive at the same location nearly simultaneously. If both are absorbed within a femtosecond (10^{-15} of second), such that the molecule cannot, quantum mechanically speaking, distinguish where one photon ends and the next one begins, then the two infrared photons can combine to equal the energy of one blue photon, taking the molecule from the ground state to the excited state and leading to fluorescence. The important advantage of the 2p process is that excitation and, a

A series of lenses and optical relays direct the laser light to the sample.

> **We can build a machine to do a lot of things better than we can, but for other things, we can't.**

few nanoseconds later, fluorescence, occur only at a single point where the laser intensity is strong enough to give rise to the near-simultaneous absorption of two low-energy infrared photons.

The two-photon microscope does create a linear cone of light, just as single-photon excitation does, but in the 2p process, the intensity of the light outside the plane of focus is too low to cause excitation. The result is that the image captured is made up of only a single sharply focused point of light, eliminating contamination from out-of-focus light.

"The image reveals only light from that plane we're looking at, without much background signal from above or below the plane," Smith says. "The brain has optical properties like butter; it's full of lipids and aqueous solutions that make it hard to see through. With normal optical imaging, you can see only the very top of the brain. Two-photon imaging allows us to image deeper down and still attain sub-cellular resolution."

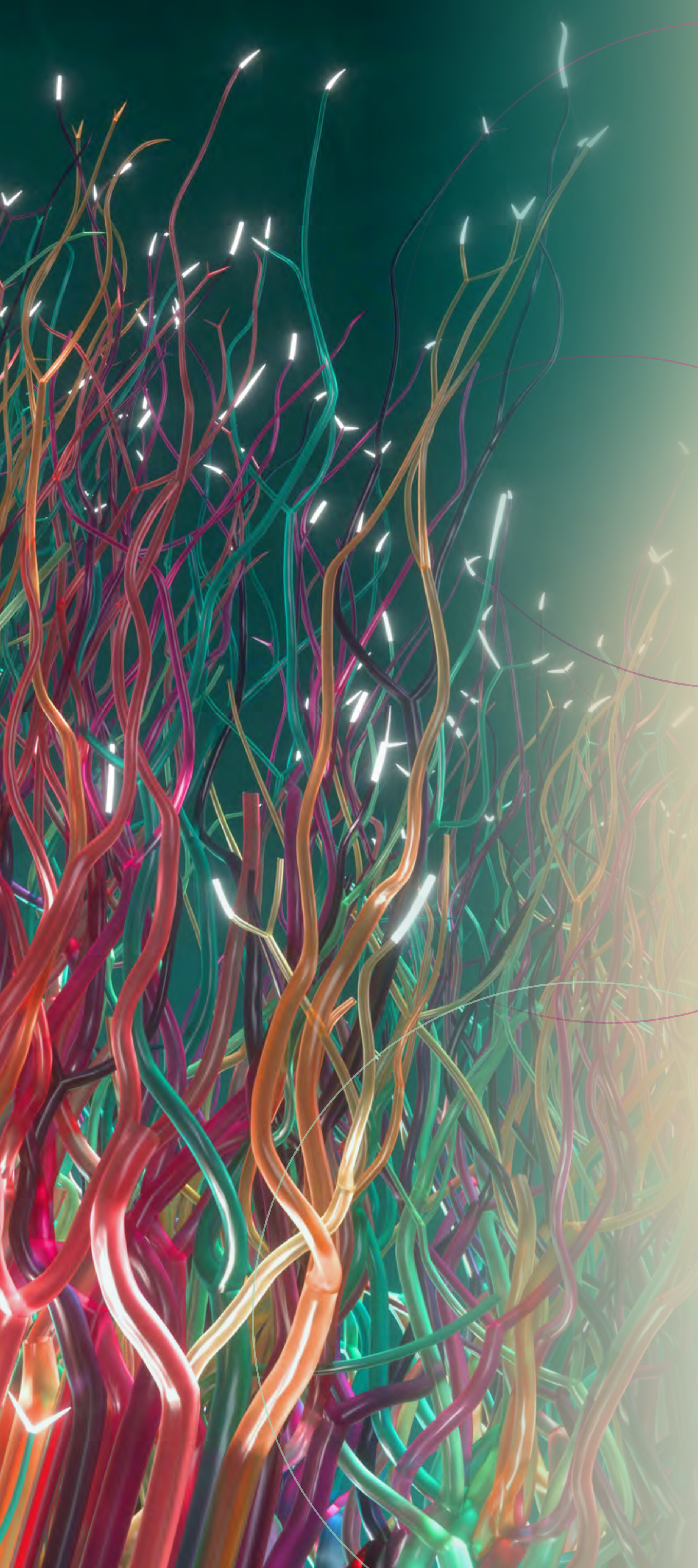
Another advantage of 2p excitation is that the lower-energy, longer-wavelength light employed in it scatters less when passing through tissue, so that it can be sharply focused deeper into tissue. Moreover, the lower-energy, near-infrared light is less damaging to the sample than shorter wavelengths, such as ultraviolet.

Smith's lab tested the device in experiments on mice, observing their brains while they performed tasks such as watching videos or navigating virtual-reality environments. Each mouse has received a glass implant in its skull, providing the microscope with a literal window into its brain.

"I'm motivated by trying to understand the computational principles in neural circuitry that let us do interesting things that we can't currently replicate in machines," Smith explains. "We can build a machine to do a lot of things better than we can, but for other things, we can't. We train teenagers to drive cars, but self-driving cars fail in a wide array of situations where humans do not. The systems we use for deep learning are based on insights from the brain, but they are only a few insights, and not the whole story. They work pretty well, but are still fragile. By comparison, I can put a mouse in a room where it has never been, and it will run to someplace where I can't reach it. It won't run into any walls. It does this super-reliably and runs on about a watt of power. There are interesting computational principles that we cannot yet replicate in human-made machines that exist in the brains of mice, and I want to start to uncover that. It's why I wanted to build this microscope."

Smith is committed to ensuring open access to the instrument, and long before this paper was published, he and his co-authors released a preprint that included the engineering details needed to replicate it. They also shared the technology with colleagues at Boston University, where researchers in Dr. Jerry Chen's lab made modifications to suit their own experiments. "This is exciting," Smith says. "They didn't have to start from scratch like we did. They could build off of our work. Jerry's paper was published back-to-back with ours, and two companies, INSS and CoSys, have sold systems based on our designs. Since there is no patent, and won't be, this technology is free for all to use and modify however they see fit."

FOCUS ON: UNDERGRADUATE STUDENT RESEARCH



Many freshman students arrive at UC Santa Barbara with only a vague idea, if any, of where they want to go in life, much less with a plan for how to get there. Especially for first-generation college students and those from underrepresented or otherwise disadvantaged groups, a big university like UCSB can feel intimidating and hard to navigate. Even for students who take a more "traditional" path to college, words like *research*, *graduate school*, and *PhD* can seem almost mystically remote, with the professional pathways they offer lying nearly beyond imagination. Fortunately, UCSB is full of resources, including the Faculty Research Assistance Program (see page 33 for a list of others), that can help students transform the mystical into the immediate by providing keys to doors of opportunity. Undergraduate research (UGR) is one time-honored way that happens.

Not every undergraduate who works in a lab on campus will become a researcher. At the very least, however, as is clear from the students and faculty profiled in this edition of FOCUS ON:, undergraduate research provides students with valuable skills and knowledge and makes them more engaged, more satisfied, and more successful students. It can also, as you'll read here, enable students to discover the passion that defines their professional future.

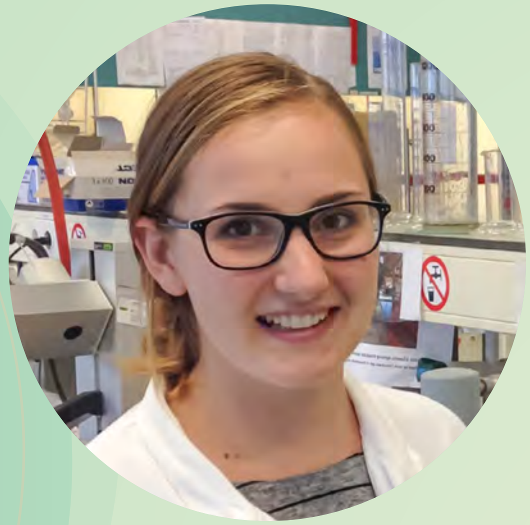
GABRIELLE HAMMERSLEY

Being raised by her single mother in a small town in Wisconsin, **Gabrielle "Gabby" Hammersley** (BS '17) recalls, "Our resources were very limited. I always felt like we had less than most people." And though Hammersley was her high school class's senior valedictorian, her circumstances made her unsure whether she would go to college. She applied quite late, and only then because one of her teachers encouraged her to.

Arriving at UCSB with a vague notion of perhaps aiming for medical school, she began as a biology major, then switched to chemistry. In her junior year, she wanted to do research to build up her resume to apply for med school. Now, she is working as a medicinal chemist at Vividion Therapeutics, a drug-development startup company that was recently purchased by Bayer Pharmaceutics, earning Hammersley a payout big enough to retire all her student loans.

"Before doing research, I didn't have any sense of direction or purpose for my life," she says. "Research was the beginning of my evolution. It gave me challenges, pushed me out of my comfort zone, and put me in a place that was kind of scary but gave me a space to grow."

"It's a success story of her undergraduate research opening up multiple different avenues of opportunity for her," says chemistry professor **Javier Read de Alaniz,** Hammersley's faculty mentor, who is also associate director of the California NanoSystems Institute (CNSI) and director of the NSF-funded BioPACIFIC MIP.



ANGEL OKORO

Like many science-minded freshmen, **Angel Okoro** (BS '20) entered UCSB under pre-med, not knowing what a PhD really was or why or how one would go about getting one, intending to major in biochemistry and become a pharmacist. She eventually graduated with a BS in biology and a minor in Black Studies and is now in her second year of PhD work at Brown University, where she studies the nervous system of *Drosophila, aka* "the fruit fly," in a supportive lab that she loves while working toward her still-forming goal of entering the medical industry, but now via the research route rather than medical school.

She traces her current trajectory directly to her UG research experience in the lab of her mentor, **Julie Simpson,** a professor in the Department of Molecular, Cellular, and Developmental Biology (MCDB). "It's so rare to find a faculty member who can see you as an individual, as a student with goals, desires, promise, and potential, and when you do find someone who reaches out and treats you like a person who has promise — well, it changed a lot of things for me," Okoro says. "Julie's lab environment made me feel I could be somebody, which wasn't something I had experienced before. I wouldn't be here without her."

Photograph by Cristina Soto Balderas

MARIANN GUZMAN-ESPINOZA

Mariann Guzman Espinoza was born in Oaxaca, Mexico. Her parents are both artists, and neither went to college. Her father is Zapotec, and his parents spoke only that language. The family moved to San Francisco when Mariann was three. She arrived at UCSB "set on going to med school" but also "really scared of going to college," not sure how she would do academically, and "not knowing where to start" her journey. Now preparing to graduate in June, having spent three years in the lab of **Craig Montell,** a neurobiologist in MCDB, she was accepted into a STEM cell master's program at San Francisco State University and has also been offered a position as a junior specialist researcher in a lab at UC San Francisco. She is considering pursuing an MD/PhD down the road.

"There are lots of possibilities, and my future plans are really open," she says.

Henry Moise (BS '21) was an average high school student in the San Francisco Bay Area and wasn't thinking about going to college. He did attend community college, and then transferred to UCSB, where he found the transition challenging during his first two quarters as a chemical engineering major. Then, he found that he could put his experience working with tools in a hardware store to good use in chemical engineering professor **Eric McFarland**'s lab. Moise is spending the current year as an employee in McFarland's startup company, C-Zero, Inc., before beginning a PhD program at Stanford, where he has already been accepted.

"I would never have thought I'd be so excited reading science papers by other groups about methane pyrolysis," he says. "It's a cool feeling to be excited about things like that, and grad school will allow me to take that further."

HENRY MOISE

THESE FOUR STORIES AND THOSE THAT FOLLOW DEMONSTRATE

with compelling consistency the transformative effects that can flow from undergraduate research (UGR) experiences for students and, some years ago, for many whose own transformative journeys were instrumental in their leading labs and mentoring UG researchers today.

By one estimate, approximately half of all undergraduates at UCSB participate in UGR, but the figure is unreliable, because students come and go from labs, and there is no central campus body to register or track them. Whatever the percentage, it is clear that as many students who *can* do UGR *should* do UGR.

Read de Alaniz vividly recalls his own transformation as an undergraduate researcher. At the time, he was an academically strong student at Fort Lewis College, in Durango, Colorado, running cross country and majoring in environmental science but without a focus on graduate school. "I had no understanding of what a PhD even was," he remembers. "I didn't know it was an option."

Then, because it paid the same as a construction summer job would, he spent three months working on a project in a professor's lab. He recalls the science being less important than "the environment, the investigation, the camaraderie." He then did undergraduate summer research at Purdue University, where he worked with graduate students, an experience he describes as "the stepping stone" that allowed him to think he, too, should go to grad school. "Undergraduate research was what got me kicked off in science and STEM," he says. "It changed my trajectory."

THE UG TRIAD

Javier Read de Alaniz

"Science courses generally do not actually teach science. Rather, they teach the resultant product that arose over centuries of science" says **Joel Rothman,** a professor in MCDB, the Wilcox Family Chair in Biotechnology, and the director of the Biomolecular Science and Engineering Doctoral Program at UCSB. "Which is to say that science is the act of striving to make new discoveries, of working at the moving edge of knowledge. To experience science, one must engage in the rich discovery process known as research and, ideally, do so within a community of other scientists."

Over the past decade, Rothman and MCDB teaching professor **Rolf Christoffersen** ran a program funded by the Howard Hughes Medical Institute called the Large-Scale Undergraduate Research Experience, an immersive six-week, 24-hours-per-week summer course taught by postdocs who would bring their lab's research into the course. "It was good for the postdocs, who got to design the curriculum and mentor the undergraduates," says Christoffersen, "and the students got a much better feel for what research is about, and the opportunity to experience how it feels to work as a scientist."

"We based our efforts on hard data that's been published, demonstrating that students who do research perform better academically," says Rothman. "It remains an open question as to what are the most important factors in research experiences that result in these positive outcomes, but there are likely three major ones."

First, he says, "Students involved in research feel part of the scientific enterprise as members of a lab group, which provides a strong sense of community. That's particularly important at a large campus like UCSB."

Mariann Guzman Espinoza (center) and her mentors, Craig Montell and Angela Morales.

"Being in a lab with grad students from all over the world and seeing the freedom and opportunities they have really opens the eyes of first-gen students and others from underrepresented groups," says Read de Alaniz, expanding on Rothman's point. "They get to see themselves as part of a bigger community beyond just UCSB, and where they fit into that structure."

That observation rings true for **Ricardo Espinosa Lima,** a first-generation student who was born in Mexico City and moved to the U.S. when he was fourteen, and whose family qualifies as low-income. He says that doing research in the lab of **Angela Pitenis,** a professor in the UCSB Materials Department who studies soft, biological, and bioinspired materials, he discovered that he likes being in a group, especially one that crosses disciplines.

"One of the biggest challenges for me is communicating science to an engineer, because the focus of a question shifts a lot depending on the lens through which we approach it," he explains. "The Pitenis lab is dominated by materials scientists, chemists, and mechanical engineers, who have very different approaches than I do as a biologist. It's been fulfilling to be in interdisciplinary spaces where I get to be challenged and to think in ways I probably wouldn't have."

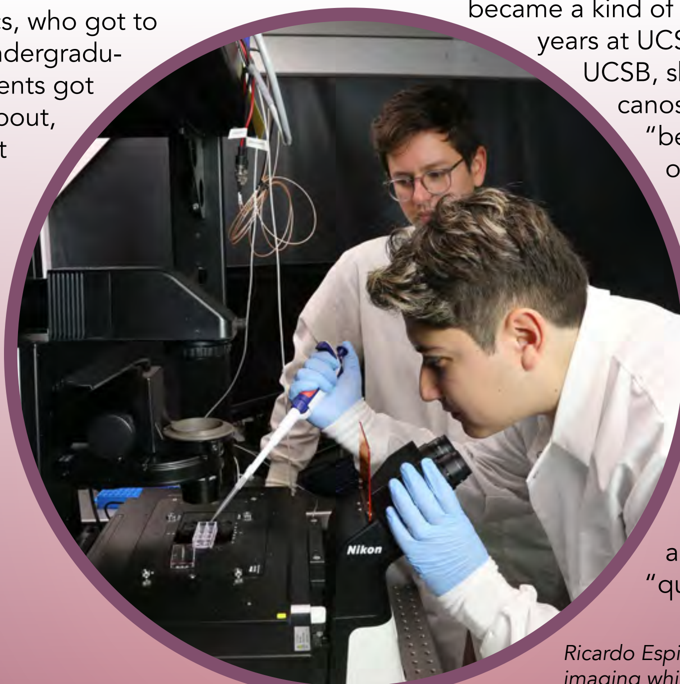
Rothman says that the second element of UG research that enhances success is "the hands-on research experience — students' direct contributions through experiments that may lead to new discoveries."

"Being in Eric [McFarland's] group made me fall in love with research and see the opportunities you get from it," says Henry Moise.

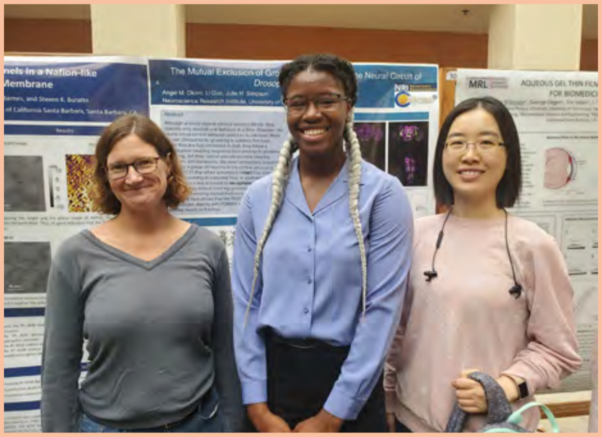
For Mariann Guzman Espinoza, her UG research experience became a kind of hub around which her highly successful four years at UCSB have revolved. Initially feeling intimidated at UCSB, she joined the Society for Advancement of Chicanos and Native Americans in Science (SACNAS), "because I wanted that sort of space where I saw other people, also first-generation who came from similar backgrounds."

At the suggestion of SACNAS upper classmen, she sought out a UG research position, finding one doing experiments in the Montell lab, where she worked closely with her PhD student mentor, **Angela Morales.** When COVID forced her to work remotely, Guzman Espinoza took the time to learn various types of software used to analyze images and experimental data.

After experiencing impostor syndrome in a way that could make her feel as though her "questions weren't good enough" or she didn't



Ricardo Espinosa Lima prepares organoid cultures for fluorescent imaging while his mentor, thrid-year PhD student Jona Rosas, looks on.



Angel Okoro (center) at a CAMP research poster session with Julie Simpson (left) and Li Guo, a graduate student in Simpson's lab who served as Okoro's mentor.

"belong in research" or "belong in my major," things started to shift while she was working as part of a research cohort during a third-year internship. She realized that she wasn't alone, that other people have impostor syndrome, and that they also make mistakes while they're learning new techniques.

From there, one thing led to another. She fell in love with research, gained confidence and participated more in her classes, became a better lab partner, spent hours in the lab, and experienced the excitement of discovery and what she describes as "such a nice feeling after struggling to master a technique and then leaving the lab after doing an experiment successfully for the first time."

She was also hired as a SIMS peer mentor for incoming freshmen. In that role, she says, "I was able to interact with new students who are low-income and first-generation, like me. I was able to share my story with them and offer some advice that I wish I had when I first arrived. I tell them that that if they want to do research, they can. It's really important to me to be able to say that, because I've always wanted to be a mentor, and I really appreciated the mentoring I got from my research experience."

Michael Gordon, the Robert G. Rinker Founder's Chair in Chemical Engineering, says he sees it as a victory that roughly half of his UG researchers have gone on to grad school. "I did undergraduate research myself and found it immensely enlightening and motivating, and if I can transfer that experience to undergrads in our lab, so that they want to go further and have a deeper experience of why the world is so cool, then I've done my job," he says. And, like Espinosa Lima, many of Gordon's students who have gone on to pursue advance degrees did not remotely consider that possibility as freshmen.

Pitenis discovered undergraduate research in her last semester at the University of Florida after being encouraged by a professor. "A ten-minute lab tour turned into a PhD and completely changed my career trajectory," she says. "I encourage my undergraduate students to get involved in research so they can gain additional skills outside of the classroom, build up their confidence, and become more competitive applicants for scholarships, industry, graduate school, or beyond."

The third important piece in the UG research experience, Rothman says, is "the enduring support students receive from an engaged and nurturing mentor, someone who looks out for them and can provide guidance, support, and validation. In large courses on a large campus like UCSB, students can feel anonymous. This direct mentoring can provide undergraduate researchers with the first truly personalized science experience."

The mentorship that Angel Okoro received as a UG researcher in the lab of Julie Simpson proved pivotal. "I wanted to do research in a lab. I didn't know what kind of research I wanted to do or what lab I wanted to be in," Okoro recalls. "I just wanted to get my foot in the door and get started."

Frustrated after contacting some 25 faculty members without success, Okoro finally was invited to what she thought would be a sit-down interview with Simpson. But after giving Okoro a tour of the lab, Simpson told her she could start to work whenever she was ready. Okoro, who had no experience at the time, recalls vividly what happened next: "I asked her about my lack of qualifications, and Julie looked me straight in the eyes and said, 'I looked at your resume, and I think you are qualified. I have full faith in you.'"

> "THE THIRD IMPORTANT PIECE IS THE MECHANISM OF HAVING A GUARANTEED MENTOR, SOMEONE WHO LOOKS OUT FOR YOU AND WITH WHOM YOU CAN INTERACT AND FEEL VALIDATED BY AND GET REAL HELP FROM INSTEAD OF BEING AN ANONYMOUS BIT IN A LARGE UNIVERSITY."

Materials professor Angela Pitenis describes undergraduate researchers as "the backbone of our lab."

WHAT UGR'S ADD IN THE LAB

Galan Moody finds that undergraduate researchers help graduate students "more deeply understand what they're doing."

It would be easy, and incorrect, to suppose that undergraduates might not have enough knowledge or experience to contribute much in the lab. In interviews for this piece, however, one professor after another indicated the diverse ways that those students bring value to the lab.

Michael Gordon says that multiple undergrads in his lab have been listed as co-authors on journal papers, and one did most of the work that resulted in a recent intellectual-property (IP) application. He says that getting to that level requires the UGRs in his lab to do more than busy work; it requires them to have enough autonomy and responsibility to take real ownership of their projects. "It's tremendously empowering to take ownership and make progress and see those milestones that you reached through your own accomplishments," he says.

Although undergraduates are usually, indeed, the least knowledgeable people in a lab, their relative "greenness" can enable them to ask simple questions that are trenchant and useful.

"On long-term projects, it's easy to get stuck in the details, and sometimes we need to take a step back and ask these more basic questions, the kinds of things that undergrads ask when first starting their research projects," says **Galan Moody,** professor in the Department of Electrical and Computer Engineering who currently has major projects in quantum photonics. "Answering the undergraduates' questions is a good way for our grad students to more deeply understand what they're doing, at a basic level, and to learn how to communicate the science."

Undergraduate contributions come in many forms. One of Moody's UG researchers, **Quynh Dang,** left her family in Vietnam when she was 16 to attend community college in Washington state, then transferred to UCSB to study electrical and computer engineering, graduated a year and a half later, and is now a first-year PhD student at UC Irvine.

When COVID protocols kept undergraduates out of the lab, Dang worked remotely to develop and construct experimental modules for a graduate course Moody was teaching. "She came to our group and, with very little experience, helped me put together the tutorials for the quantum photonic teaching labs for my courses," Moody says. "She was amazing," adding that she also contributed significantly to his research on quantum light sources, resulting in co-authorship on a paper published in *PRX Quantum*.

Eric McFarland says that while undergraduates generally contribute little to forwarding his research, he finds it rewarding to see students evolve from when they start in the lab and "know really nothing to becoming someone who can see how what they're doing makes a little bit of a difference and are excited about it and want to go to grad school."

For Read de Alaniz, even the students' youthful enthusiasm is a benefit. "One of the best parts about working with undergrads is that they have this curiosity that, I think, reminds a lot of us why we got interested in science in the first place," he says.

Angela Pitenis considers her undergraduate researchers "the backbone of our lab," and says that during the COVID closures, "Our research was severely impacted by our undergrads' not being there. And they weren't missed just in the day-to-day running of the lab, but also in serving as kind of sounding boards for ideas that the grad students and I have. Sometimes, it takes a simpler question from an undergrad to really probe the depth of a question and to encourage graduate students and me to think about the problem in a deeper and more fundamental way."

"SOMETIMES, IT TAKES A SIMPLER QUESTION FROM AN UNDERGRAD TO REALLY PROBE THE DEPTH OF A QUESTION AND TO ENCOURAGE GRADUATE STUDENTS AND ME TO THINK ABOUT THE PROBLEM IN A DEEPER AND MORE FUNDAMENTAL WAY."

Julie Simpson maintains a small army of about forty undergraduate researchers in a group established during COVID restrictions to trace neurons in large electron microscopy (EM) data sets. Recently they found some surprising types of sensory inputs to one of the neurons of interest. "The undergraduate students arrive without preconceived ideas, which is helpful, because if I or the grad students or postdocs had seen those inputs, we might have dismissed them; we might have said, 'No, that can't be right,'" Simpson explains. "But they traced it, and it is right. People bring different past experiences and talents to this work, and the undergraduates are contributing to real scientific discoveries."

SCIENCE FOR CHANGE

Then-PhD student Sammy Davis (second from left) with undergraduate researchers.

For all of their varied contributions to the labs where they work, the students themselves benefit in ways that, often, permanently change them, helping them to grow academically and personally while pointing the way to previously unimagined careers.

Ricardo Espinosa Lima will graduate from UCSB this June and was, at press time, waiting to hear from graduate programs at UCLA, UC Berkeley, and UC San Francisco, with the intention of pursuing a PhD in stem cell biology or bioengineering. He says that his UGR experience, which included participating in the STEP and EUREKA programs, was decisive. "Those programs helped me realize what I'm capable of and what being a biologist is," he says. "The support was so good. Ofi [**M. Ofelia Aguirre Paden,** Director of the Center for Science and Education Partnerships (CSEP)] and Sammy [CSEP Undergraduate Research Programs Coordinator **Sammy Davis**] were always asking, 'Is there any way we can support you?' Their support launched me into the science world."

Galan Moody makes an often-repeated point when he says, "Undergraduate research is often more open-ended than what students encounter in coursework labs. You don't have a lab manual telling you the steps. You don't know exactly what you're doing until you start, and you have to figure out what to do on your own. So, developing those skills as an undergrad is important. It's the real world of engineering."

Research can be tremendously impactful in undergraduates' becoming more academically interested, engaged, and successful. "I have countless examples of students who were below a 3.0 GPA and probably wouldn't have made it through their major without the research experience that kept them engaged," says Read de Alaniz. "They realized that to keep doing this thing they discovered they like doing, they have to keep their grades up. It helps them to balance the two and to see why it matters to excel. They think, *That career could allow me to do things I want to do.* That's an eye-opener for many of my first-generation students or students from underrepresented groups. Maybe for the first time, they see a future."

Eric McFarland refers to himself as "hard-nosed" about his requirement for UG researchers in his lab. "They have to raise their GPA every quarter. If they don't, they have to leave," he says. "It's gratifying to see a student who comes in and is not in the top ten percent of their class and by the time they leave me, they are. Frankly, those are the students I want, the ones who have the potential to be a lot better."

"The [McFarland] lab was very demanding, and I needed to spend a lot of time there, and that forced me to focus even more on my courses, because there just wasn't time to fool around," Moise remembers. "You have to get good grades to keep working in the group, and that was a really good motivator for me."

For Moise, lab work proved to be the key to real learning. "I'm much more of a hands-on learner, and there were so many vocabulary words, concepts, and ideas that kind of

M. Ofelia Aguirre Paden (left) and Dotti Pak have supported hundreds of undergraduate researchers.

Allison Koopman with lab colleagues during her CISEI summer internship in Japan.

escaped me just reading them in a textbook," he says. "It was kind of embarrassing that a simple concept like vapor pressure escaped me. I knew what it was, but I got a really solid grasp of it only after I worked in Eric's lab and saw the consequences of what it does. There are so many things you learn being in a group, like showing you can take a project and run it. You get to take ownership. You get to say, 'These are my results, and I can defend them.'"

Allison Koopman (BA '19), who graduated from a public high school in San Jose, California, and is now pursuing a PhD in materials science at the University of Delaware, describes herself as "a low-achieving high achiever."

She took ownership almost from the moment she arrived at UCSB, participating in summer research every year she was here. She began with the two-week SIMS program the summer before her freshman year, then spent eight weeks the following summer at the University of Texas El Paso (UTEP) as part of the PREM program. She participated in the CAMP program the summer before her sophomore year, and conducted research at the Tokyo Institute of Technology as part of the CISEI program. During her sophomore and junior years, she also worked in the labs of UCSB materials professors **Craig Hawker** and **Chris Bates,** where she, says, "I gained a love for polymer science that I'm still pursuing into my PhD. They're crazy smart, and it was interesting to see the gears whirring in their heads."

Enrolled in UCSB's highly competitive College of Creative Studies (CCS), where she majored in chemistry and biochemistry, Koopman discovered the importance of trying to do undergraduate research via a post on a Facebook group for incoming CCS freshmen, where she learned about the SIMS program from one of her future dorm mates.

"That post was very important," Koopman says, "because without it, I wouldn't have done SIMS, and without SIMS, I wouldn't have known to apply in February for summer internships after my freshman year. I wouldn't have had the momentum to go to UTEP that summer, and it was UTEP that led directly to me getting a place in the other labs where I've worked."

Koopman's experience underscores the importance for undergraduates of being attentive to opportunities — whether they show up as a social media post, a university email, a workshop, or a notice on a club bulletin board — and taking action when they appear. While various programs and offices in the COE and elsewhere in STEM disciplines at UCSB do an outstanding job of informing students about the value of pursuing UGR opportunities, it's easy enough for a student to miss class on the day of a research presentation or to fail to read an email about research opportunities that could change their lives.

Like many UG researchers, Koopman says she "became hooked" on lab work right away, and when she was introduced to polymers in the Hawker and Bates labs, she found the path to her future while doing challenging work that dramatically increased her confidence.

"I was working with [project scientist] **Morgan Bates,** who had me do a lot of the physical chemistry. I would ask for help only if I was having a big problem; otherwise, I had to figure out stuff myself," she says. "It was fun, even if it was kind of panic-inducing at the time. Now, I find I'm quite confident doing all this chemistry and setting up polymerizations. I am confident that I can do research, that I can do my own research, and that I can get my PhD."

Having recently bought a house in Delaware, Koopman says that she might like to work eventually at one of the several national labs nearby or in industry — both DuPont and W. L. Gore & Associates (makers of Gore Tex) have campuses near her.

Sophia Uemura (BS '20) knows what it's like to get in a bit over her head. Now pursuing a PhD in materials chemistry at UCLA, Uemura, who double-majored in chemistry and biochemistry, used tenacity to get her UG position in the lab of chemistry professor **Lior Sepunaru.** She says, "I approached him in his office, but he didn't have a spot, so I went back every day, saying 'I would love to be in a lab; I would love to get research experience.'" Sepunaru told her that he didn't have a graduate student to mentor her at the time but did have an idea of a project she could take on and asked if that was OK.

She said yes, she recalls, "not knowing at the time that, traditionally, as an undergrad, I would be working under a graduate student. But I took on a project related to silver nanoparticles on my own, under Lior's supervision. While I had a lot of responsibility beyond what an undergrad usually has, it was important in helping me understand that I would like to continue doing this in the long term."

Tenacity earned Sophia Uemara a position in chemistry professor Lior Sepanaru's lab. She is now pursuing her PhD at UCLA.

DIVERSE SUCCESSES

Students who do UGR vary widely, and faculty have a range of criteria for selecting them. Read de Alaniz says he is not particular about the kind of experience students have when they apply to work in his lab, because he sees hosting undergraduate students, especially those from underrepresented groups, as "a way to expand the STEM pipeline," adding, "My ultimate goal is to expose students to real research and see if they like it as much as I did. I usually try to identify a few students who are coming from a nontraditional pathway and don't know what UGR is or what a science degree might enable them to do, because they're not exposed to the role models who can show them."

For Gabby Hammersley, her "trajectory-changing" research experience in the Read de Alaniz lab catapulted her to one success after another. "From Javier's lab, I was included in two research papers, one of which was a first-author paper, which is kind of unheard of for an undergraduate, I think," she says. "That research got me into CISEI, which allowed me to study abroad for a summer in the Netherlands, where I did more research. After that, Javier introduced me to an opportunity to do a two-year post-baccalaureate program known as CRTA (Cancer Research Training Award), doing organic synthesis under a professor at the National Cancer Center at the National Institutes of Health, which resulted in two more publications, another of which was a first-author paper. So, that little bit of chemistry I learned in his lab took me so far."

Angel Okoro, too, saw her UG research experience yield a cascade of opportunities. It's one reason, she says, "I'm constantly on the UCSB subreddit page advocating for people to do more research, because there are a lot of benefits that people don't consider, like getting course credits for being a UG researcher. And I got the Lewis Stokes Alliance Fellowship because I was doing research, which also funded part of my research hours the next quarter, which helped me afford grad school applications, take my GRE classes, etc. They also paid for me to fly to Hawaii for a research conference, and that helped me get into several graduate school programs, because I was able to talk personally to recruiters. Research opened so many doors that I didn't know existed."

> **"FIRST-GENERATION STUDENTS, ESPECIALLY, HAVE LIMITED ROLE MODELS IN RESEARCH. IT'S COOL WHEN A STUDENT SEES A NEW DOOR OPEN, AND THEN TO SEE THEM GOING FOR THINGS THEY'RE EXCITED AND QUALIFIED TO DO AND COULDN'T HAVE IMAGINED GOING FOR PREVIOUSLY."**

For her CISEI summer, Gabby Hammersley did organic synthetic chemistry research in the Netherlands.

Walter Boggan works on the front lines in supporting students from diverse backgrounds find their way to research. As director of Admissions, Outreach, and Diversity Initiatives for UCSB Graduate Division, Boggan oversees the Academic Research Consortium. The summer pipeline program, which is open to students from underrepresented groups attending colleges from Bakersfield to San Diego, he says, "gives students from diverse backgrounds who might not otherwise have them opportunities to get experience at an R1 Institution."

Boggan says that he sees a big increase in confidence among students in the program, many of whom experience impostor syndrome. "I like to ask the question: *Do you feel like you belong here?" he says.* "Every year, at least five or six students write to me after they complete the program and say, 'This program gave me confidence to know that I can do this work at this level.'"

"A lot of the students I meet have no research experience, and first-generation students, especially, have limited role models in research," says CSEP's Davis. "It's cool to witness it when a student sees a new door open, and then to see them going for things they're excited and qualified to do and couldn't have imagined going for previously."

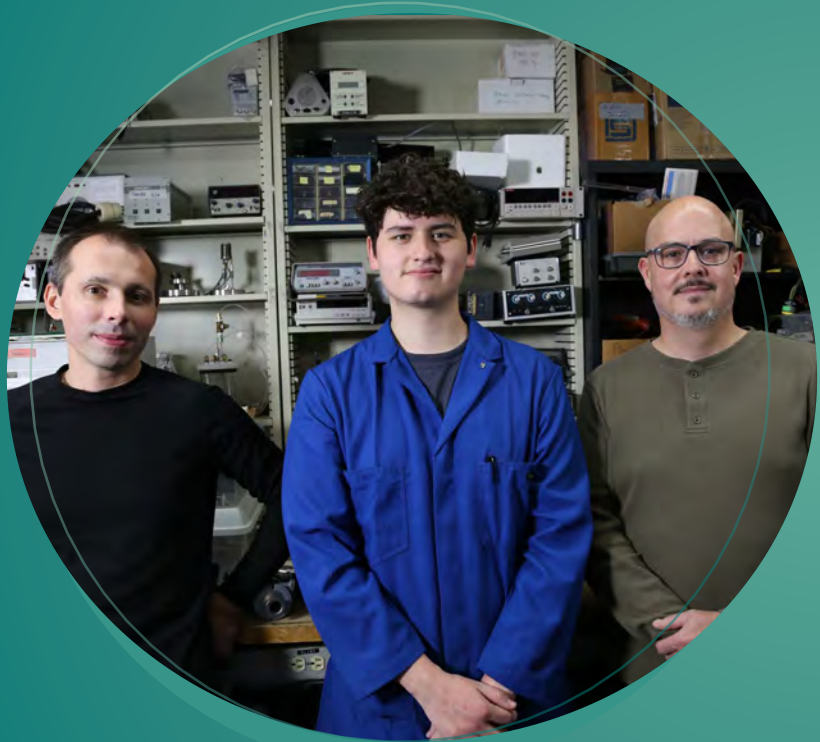
Mario Castellanos, executive director of the UCSB Office of Education Partnerships (OEP), coordinates a number of experiential programs aimed at diversifying students in the STEM pipeline and overcoming achievement gaps experienced disproportionately by students who take non-traditional paths to UCSB. In one such project in the UCSB-Smithsonian Scholars Program, community college students are working to develop an algorithm to optimize the sorting and counting of wildlife images from remote cameras on Santa Cruz Island. Working there, students have to combine GIS and field-based data points, such as road locations and vegetation, as well as a sampling protocol and instructions for handing off the work to other students.

"They had to do it all from the ground up," says Castellanos, who is an ecologist and mentors students in the field for the program. "Our network provided equipment, transportation, training, and safety. They had to develop a research design and be able to communicate about it, which required a range of skills that are not normally taught but that resonate with industry professionals.

"It's transformational for the students who come to us having no access to such experiences and not knowing how to take the first steps," Castellanos adds. "I see huge changes after that direct experience. Literally getting their hands dirty in an outside environment, they get inspired and start to tune in to things that they didn't learn in class."

Diego Lopez, a first-generation senior in chemical engineering who works in Michael Gordon's lab, says, "I had tons of impostor syndrome. It was something I dealt with until probably junior year."

Emily Lopez (no relation to Diego), is a first-generation student who says that growing



Diego Lopez (center) with Michael Gordon (right) and postdoctoral researcher and mentor, Oleksandr Polonsky.

Junior environmental engineering major Ricardo Estrada visits a camera trap site on Santa Cruz Island.

up, "I didn't have academics in my life." Now, as a McNair Scholar and a senior mathematics major in CCS who does UGR in the lab of mathematics professor **Katie Craig,** she does do research — so effectively, that, just before spring quarter, she was trying to decide among offers she had received from UC Davis, UC San Diego, Cornell University, and the University of Colorado Boulder, all of which had accepted her into their doctoral programs.

Getting to this point required Lopez to overcome impostor syndrome, which, for her, shows up as anxiety. "Even though I'm in the honors college, mathematics is a very homogeneous, male-dominated field with not many female-identifying students," she says. "It often felt like a boy's club, and I'd sometimes feel excluded and wonder if I was smart enough. Doing my grad school applications, I wondered if I was qualified to pursue it. But, yes, I am."

UG research played a central role in her coming to that self-affirmation. "It was all the programs I did," she says. "First, it was, *Am I qualified enough to get into the SIMS research program?* Yes, I am. Then, *Am I qualified enough to get into a more involved research project in EUREKA?* And I found that yes, I could do that. And then, *Could I do a math-specific project with the SMALL Math Research Experience for Undergrads?* And I found that I can do that, too. Now, it's, *Can I actually apply my math in the machine-learning realm?* And the answer to that is also, yes, I can."

Despite her many successes, Gabby Hammersley says that she still struggles with impostor syndrome. "I have to hype myself up in a sense, remind myself of what I've accomplished." But even then, she adds, "Occasionally, I'll think, *Do I really deserve to be here? The other students might have worked harder,* which can make me think that maybe I wasn't supposed to be where I am now."

But there she is, prospering amid her lingering, clearly unfounded doubts, succeeding by a combination of ability, effort, opportunity, and something she likely shares with a lot of the undergraduate researchers profiled in this piece. "I think my strongest quality is probably having grit and perseverance," she says. "Just coming from where I did and not knowing anything about research and begging Javier to get me into the lab and just making the best out of every situation. If something goes negative in the lab, I don't let it affect me. You have to just roll with the punches and keep thinking and be innovative."

Having worked through her own obstacles, Emily Lopez is now helping to build the confidence and make opportunities available to others, especially students from underrepresented groups. She says that her arc in SIMS — she participated before her freshman year and served as the SIMS student coordinator in 2021 — "goes to show, I

"I HAVE PURPOSEFULLY OR ACCIDENTALLY SURROUNDED MYSELF WITH PEOPLE WHO INSTILL CONFIDENCE IN ME, SO THAT I CAN WALK ON MY OWN TWO FEET. THERE ARE A LOT OF SOCIALLY MINDED EXTROVERTS AT UCSB WHO HELP PULL YOU OUT OF YOUR SHELL.

think, that by investing in undergraduates, you are also creating leaders who can spark systemic change for the better in the STEM field.

"There's this intellectual curiosity I have for the research," she adds, "but also a social aspect, a desire to try to create spaces, role models, and an environment I wish I'd had starting out as an undergraduate. That's what I'd like to do in the future: create spaces where people can be their authentic selves and reach their highest potential."

Increased confidence is clearly a major and widely noticed benefit that students derive from their UG research experiences.

"I think one of the most amazing things that I see in this work is students' expanded view of what is possible and what they are capable of achieving," says **Julie Standish,** who as intern coordinator for the MRL, provides multiple forms of support to propel students toward their academic goals while expanding the limits of what they might have thought was possible. "It is wonderful to witness their transition to being more confident in themselves and to realizing that their career and academic goals are obtainable."

"I've worked with several students in these programs who, before they began UGR, were extremely shy and lacked confidence," says Davis. "When you interviewed them, they were overcome with nerves and couldn't finish a sentence. After one summer of research, they're giving fifteen-minute research talks to a group, cracking jokes, relaxed and full of confidence. Their whole demeanor and personality change, and then they get into really competitive, top-level programs at UCs and elsewhere. It's a great achievement."

Okoro, whom Simpson describes as "a force to be reckoned with," says of her success to this point: "I think it's because I have either purposefully or accidentally surrounded myself with people who instill confidence in me, so that I can walk on my own two feet. There are a lot of socially minded extroverts at UCSB who help pull you out of your shell. I don't know if that's the case everywhere. I have friends at other schools who have not had that kind of experience."

The rewards flow in both directions. "I got my start in research through undergraduate lab experience," Simpson says. "I discovered that I loved research science, so it's an honor to be able to give that opportunity to other people. I'm delighted that Angel enjoyed what she did in the lab enough to want to keep doing it on her next educational step."

Pitenis echoes that, saying, "I am motivated knowing that I can facilitate my students' journeys by having a lab that is accessible to them and comes with a built-in community of students and faculty to support them along the way."

The seed of Diego Lopez's undergraduate research was planted early but was reflected in a self-admittedly naïve notion. "I always thought the clean room was so cool and that the people in there were the ones doing all the cool research you hear about on the news. I wanted to experience it," he says, recalling that, on the other hand, "Research was always intimidating to me. I had no idea how to find those opportunities."

He also faced a central fear that stopped him for some time. "I thought the last thing a professor would want is a freshman with no experience to get in the way or mess up the lab or take up time," he says. "I think I was worried about being told no. You just have to ask, but I didn't know that as a freshman, or even as a sophomore."

Walter Boggan has seen a big increase in students' confidence after their undergraduate research experiences.

Emily Lopez (center) with her mathematics mentors, professor Katie Craig and assistant teaching professor Karel Casteels.

> I THOUGHT THE LAST THING A PROFESSOR WOULD WANT IS A FRESHMAN WITH NO EXPERIENCE TO GET IN THE WAY OR MESS UP THE LAB OR TAKE UP TIME. I THINK I WAS WORRIED ABOUT BEING TOLD NO. YOU JUST HAVE TO ASK, BUT I DIDN'T KNOW THAT AS A FRESHMAN.

After hearing MRL Education Director **Dotti Pak** explain the RISE program at a career services event, Lopez started trying to find professors whose research interested him. Michael Gordon rose to the top of his list, and with persistence, Lopez got in.

He says his confidence grew by having to speak in front of the group nearly every day in the RISE program. That continued in Gordon's lab, where, he says, "My mentor, [postdoctoral researcher] **Oleksandr Polonsky,** had this attitude 'to just go for it.' Before, I wasn't that kind of person. I was too afraid of doing something wrong. But Oleksandr's attitude kind of rubbed off on me to try it out and see what happens. Now, I use that outside of research, too."

Gabby Hammersley, too, says that her confidence is growing: "I can see now that I really did accomplish a lot. I validated myself in a sense, and proved that I was capable of doing things I never would have thought of to begin with. It has a lot to do with Javier being an advocate, seeing something in me that I didn't see in myself, and pushing me."

Ironically, she adds, having started with an ill-formed notion of being a doctor, "It was great to find by doing research that I could be in medicine, actually making medicine like I am now, without being in medical school. I'm using all the same skills."

Still, there are more students who could benefit from doing UG research than there are positions for them in labs, and, observes Sammy Davis, circumstances arise that can prevent first-generation and low-income students, especially, from taking advantage of the opportunities that do exist. "We have many students from working-class families who have to pay their way and have two or more jobs," she says. "The challenge for them is that, to get a good UGR experience, they need to devote five to ten hours a week to research, and many of them just can't do that. A big challenge at UCSB is to ensure that UG research is inclusive and available to the entire student body."

Providing funding to broaden the pipeline is therefore critical, because, as mechanical engineering professor and the College of Engineering's Associate Dean for Undergraduate Studies, **Glenn Beltz,** says, "It happens all the time that a student takes advantage of an undergraduate research opportunity and then flourishes."

MANY STUDENTS TAKE THEIR FIRST STEP TOWARD RESEARCH EXPERIENCES THAT CAN LEAD TO UNFORESEEN SUCCESSES IN UNIMAGINED CAREERS BY ATTENDING AN OPEN HOUSE FOR ACCEPTED STUDENTS DURING SPRING QUARTER, WHERE THEY CAN GATHER INFORMATION ABOUT PROGRAMS TO SUPPORT UNDERGRADUATES, LIKE THOSE ON THE OPPOSITE PAGE.

A PARTIAL LIST OF RESEARCH-FOCUSED PROGRAMS FOR UCSB UNDERGRADUATES

CAMP

CAMP (California Alliance for Minority Participation) One of an array of programs administered by the UCSB Materials Research Laboratory (MRL), CAMP provides resources and opportunities to students from underrepresented groups (URGs) in STEM fields.

CISEI

CISEI (Cooperative International Science and Engineering Internships) Another MRL program, CISEI sends UC science and engineering undergraduates to international partner institutions for a ten-week summer research experience.

CSEP

Center for Science and Engineering Partnerships (CSEP): Based in the California NanoScience Institute at UCSB and offering diverse research programs for undergraduates.

EUREKA!

EUREKA!: An enrichment program focused on introducing first-year STEM students to the broader science community on campus and providing exposure to research through academic-year internships.

MARC U*STAR

MARC U*STAR (Maximizing Access to Research Careers - Undergraduate Student Training in Academic Research): A two-year research program aimed especially at students from URGs who are interested in biomedical research, leadership development, and graduate school preparation.

PREM

PREM (Partnership for Research and Education in Materials): The MRL-run program affords students from UCSB, the University of Texas, El Paso, and Jackson State University in Mississippi the opportunity to do a ten-week summer research exchange at another participating school.

RISE

RISE (Research Internships in Science and Engineering): Sponsored by the MRL, the program provides research internship opportunities in a variety of fields.

SIMS

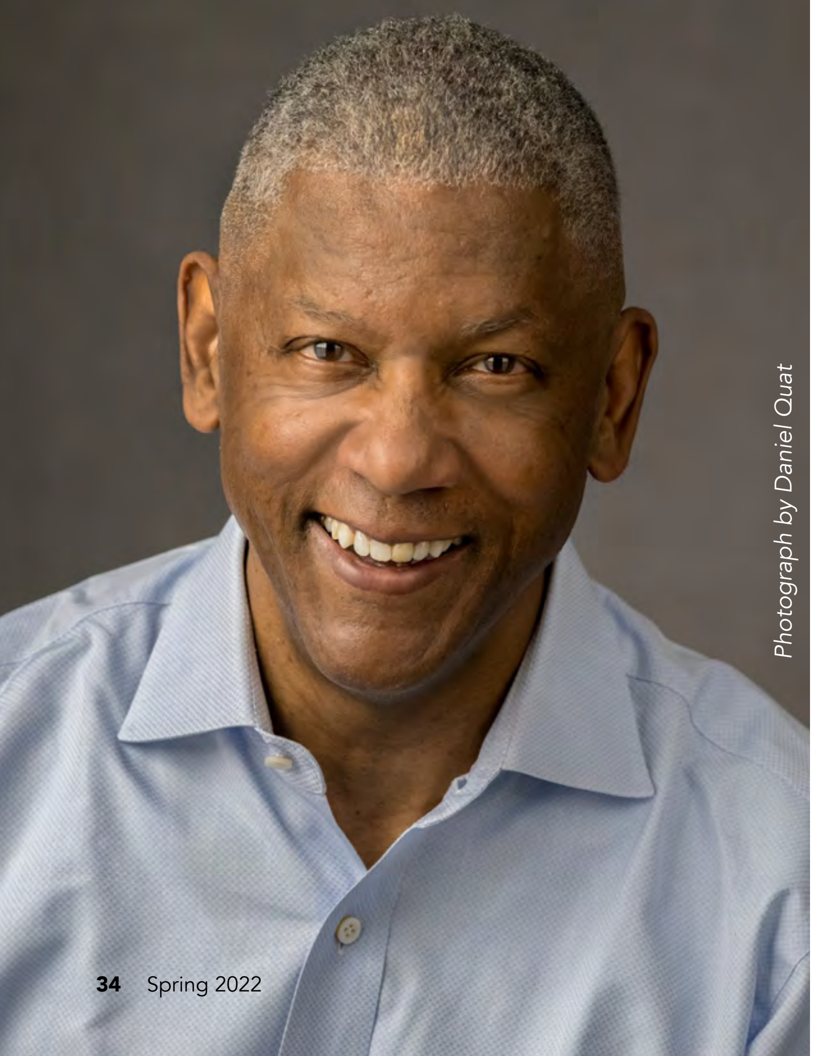
SIMS (Summer Institute in Mathematics and Science) Administered by CSEP, a three-week program offering admitted students academic preparation and an introduction to research during the summer before their freshman year.

UC LEADS

UC LEADS (Leadership Excellence through Advanced Degrees): Administered by the Graduate Division at UCSB, the UC-wide program is designed to identify upper-division UCSB STEM students who have the potential to succeed but who have experienced situations or conditions that have adversely impacted their advancement.

Champion of Engineering

Darryl McCall's COE Roots Run Deep



Photograph by Daniel Quat

Darryl McCall graduated from UCSB with a BS in Chemical Engineering in 1978 and spent the next thirty years at Procter and Gamble, eventually leading a global business and several global supply chains. He was hired by Coty in 2008, where he served as Executive Vice President until retiring in 2014. McCall currently resides and owns his own consulting company in Santa Fe, New Mexico. He co-chaired the committee for the endowment to renovate and maintain the **Robert J. Rinker** Teaching Lab, where undergraduate ChemE students receive critical hands-on training. He served on the department's External Advisory Board from 2005-'15 and has donated generously to the COE, with a focus on increasing access to STEM education and careers for first-generation, minority, and otherwise underrepresented or disadvantaged students. He spoke with *Convergence* in March.

CONVERGENCE: *You have taken on considerable responsibility in your career. What advice do you have for young engineers aspiring to achieve similar levels of leadership and responsibility?*

DARRYL MCCALL: Master your craft first, and early in your career; you likely won't have time later. Solve for x when necessary, and for the fun of it. Honing and challenging a curious mind, in your chosen discipline or not, will pay untold dividends.

You must also establish a reputation; it is what gives you the standing to be considered for new opportunities. You build a reputation through integrity, experience, and the results you achieve. Your ability to make a distinctive contribution, beyond the norm or expectations, will contribute to your reputation, and give you greater satisfaction in whatever you do. Toward that end, mobility can also be important, as learning from new relationships and in different cultures accelerates development.

C: *As a UCSB ChemE alumnus, what motivated you to support the renovation of the Rinker Undergraduate Teaching Lab?*

DM: While I was chairing the Chemical Engineering Department External Advisory Committee (EAC), students frequently complained to me about not having a relevant and reliable ChemE 180 Laboratory, which is essential for learning and for the enjoyment of problem-solving. The Rinker Lab provides an opportunity to combine theory and computation with practical experience, thus accelerating the preparedness of graduates for the realities of a job, an important concern for employers.

C: *Did you feel well prepared for your career as a UCSB graduate? What were some of the most impactful elements you recall during your time here as an undergraduate?*

DM: I felt prepared to begin work as a process engineer at either Dow Chemical or Procter & Gamble, and I joined the latter. Dr. Rinker's 8 a.m. classes and frequent homework, my independent study of biomass conversion, and camaraderie among classmates who also joined P&G in several locations, all contributed to my confidence.

C: *Can you talk about the Darryl McCall Technology Awards, which gave cash awards to minority students trying to adapt during COVID?*

DM: Research shows that people of color leave STEM studies in greater proportions than whites and Asians. COVID-19 had the potential to worsen these regrettable losses for students of color at UCSB, owing to a lack of access to reliable internet service or a quiet place to study, or a need to contribute toward family income.

I was introduced to the MESA program by Dr. Rinker in the nineties, and at the onset of COVID-19 I saw an opportunity to support STEM students of color who were moving to remote learning. During the past year of virtual classes in 2020 and 2021, more than sixty first-generation college, low-income and underrepresented STEM students received assistance of their choice. This ranged from purchasing a modem, to creating a personal study space at home, to upgrading a computer, to subscribing to an internet service.

C: *What is your view on the value of diversity generally, and to the importance of broadening access to STEM fields in higher education and beyond?*

DM: Regarding the value of diversity, one only needs to look at UCSB's excellent reputation for research as evidence of the benefits of a diverse approach to most projects. It is the deliberate inclusion of multiple perspectives, experiences, and disciplines that has led to its world-class standing in interdisciplinary research.

Supply of talent is a significant challenge when attempting to promote race and gender diversity in STEM fields. My focus in education is primarily toward improving the supply of STEM students of color. This applies to pre-K through university — and beyond. Attrition in STEM fields for underrepresented minorities doesn't end upon graduation.

C: *Despite being recognized officially as a Hispanic-Serving Institution, Latinx students in the COE often struggle to adjust, and have higher dropout rates. How can UCSB expand the pipeline to the COE for Latinx students and those from other underrepresented groups, and support them to succeed once they are here?*

DM: A pipeline is an apt analogy to describe the end-to-end nature of this problem: supply through a leaky system must exceed the demand. Two important clarifications: first, this system encompasses 20 to 25 years of education and, second, demand is best defined by the attainable respective demographics in the catchment area for the COE.

A recent example can point a way forward. When I graduated in chemical engineering, there were no female faculty. Now, twenty percent of ChemE faculty are female, and they are serving as role models for aspiring female STEM students and academics. Many efforts over many years have contributed to this success.

To achieve graduation rates commensurate with the COE catchment, particularly for Latinx students given UCSB's designation as a Hispanic-Serving Institution, leadership must find ways to match the success we have had in hiring female faculty.

I have long advocated for African American faculty at the university to serve as role models for students of color in chemical engineering. I will continue to direct my energies toward reducing attrition among underrepresented students and inspiring them to believe that they can succeed in STEM.

C: *Can you talk a little bit about your work as a UCSB Foundation Trustee? What have you found rewarding about that service?*

DM: I was humbled and honored to join Richard Breaux's (Dick) Foundation Trustee executive team during 2017 and 2019. This gave me an opportunity to understand how the university worked, beyond the purview of a department, and to influence its direction. A couple of exciting experiences were witnessing firsthand the exceptional leadership of **Chancellor Henry Yang,** the devoted loyalty of our alumni, and the sincere, energetic interest of the trustees to improve the university and its standing within the UC system. Importantly, Dick understood the benefits of assembling a diverse executive team during his tenure despite the challenges in doing so.

C: *At the dedication of the Rinker Lab, you said, "My class of '78 have all been successful, but you don't succeed individually." You then asked successful UCSB alumni to consider giving back, as you have. Why is that so important?*

DM: As a first-generation college attendee from a mobile enlisted military family of eight, I found it very challenging to satisfy the curriculum and graduate in four years. Four years was the norm, but in my case, it was an imperative, as I was married with a son throughout my studies at UCSB. I needed a job. Similarly, working in corporate America as an engineer of color in Cincinnati during the '70s and '80s was a formidable adjustment for me. P&G was also transforming to embrace diversity of race and gender. Despite my determination to succeed, it would not have happened without the support, advice, and encouragement of others while at UCSB and during my career.

My first tutor at UCSB was one of four African American pre-med students at the time. Fortunately, **Dr. Gerald Cysewski** agreed to sponsor my undergraduate thesis in biomass conversion, and Dr. Rinker accepted my application to attend his polymer systems course, ChemE160, out of sequence. In my senior year, my classmates accepted me into their study groups when I finally moved sixty miles closer to campus to reside in married student housing. I could not have graduated without this support and encouragement, for which I have always been thankful.

Isaac Newton's observation to the effect that, standing on the shoulders of giants, one can see further and more clearly than otherwise, has been inspirational for me. Upon graduating, it became my turn to give back, and through my example, I have hoped to encourage my classmates, colleagues, and others to do the same. Now that there are roughly twelve COE graduating classes from UCSB in retirement from careers, since the first grads, in 1965, I want to encourage these successful alumni to contribute more of their energy and ideas to UC Santa Barbara.

IN VIS IBLE WAR RI ORS

WE LOOK AT MORE REMARKABLE WORK DONE BY UCSB FACULTY AND HEALTH-PROFESSIONAL COLLABORATORS TO FIGHT THE PANDEMIC

A GRADUATE STUDENT'S GREAT LEAP IN OMICRON DETECTION

Last December, the highly transmissible omicron variant threatened to again overwhelm the already beleaguered U.S. healthcare system. That was when UC Santa Barbara doctoral student **Zach Aralis** stepped into the fray, developing a test that could distinguish omicron from delta and serve as a template for defense against future major COVID variants.

The importance of making that delta-omicron distinction through testing was foremost in the mind of medical professionals at the time, because it had implications for life-saving treatment using monoclonal antibodies. "There are currently three monoclonal antibody options for treatment against the SARS-CoV-2 virus," said Cottage Health infectious disease specialist (and UCSB alumna) **Dr. Lynn Fitzgibbons.** But only one of the three, Sotrovimab, proved effective against the omicron variant. Treating an omicron infection with any of the other COVID–specific monoclonal antibodies would be, she said, "like shooting blanks," while unnecessarily exposing patients to possible side effects and allergic reactions.

As cases of new COVID infections grew, however, there was no quick way to determine who had the omicron variant and who had delta or any of the other previous major variants. Genomic sequencing took weeks to return results. Meanwhile, caseloads climbed precipitously.

"The big unknown through that third week of December was how many cases were actually omicron," Fitzgibbons said. Data from the State of California's variant assessment program were weeks behind, and, to compound the problem, Sotrovimab had become scarce, making it even more crucial that the therapy be given only to people it could help.

Further, the virus was so new that no company had yet been able to develop and offer a test. "We came to the conclusion that we'd have to make it ourselves," said **Stuart Feinstein,** a UCSB professor of molecular biology, the UCSB COVID-19 Response Team coordinator, and a member of the Local Variant Task Team — a collaboration between the university, local healthcare providers and the Santa Barbara County Public Health Department (SBCPHD) formed to monitor for new and possibly dangerous versions of the SARS-CoV-2 virus.

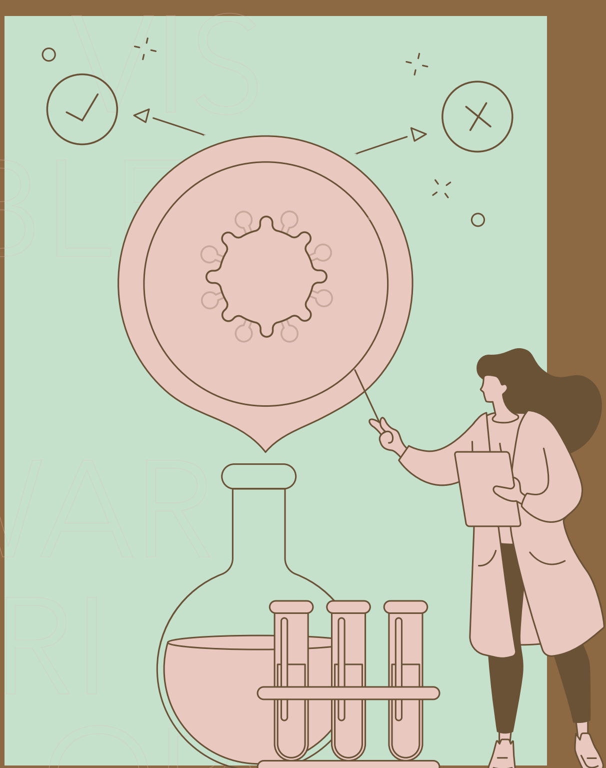
The task fell to Aralis, a graduate student in the molecular biology lab of **Professor Carolina Arias,** who for the past two years had been sequencing samples at the UCSB CLIA-licensed laboratory as part of the campus community's sophisticated variant monitoring program.

Aralis got to work developing a test over the holiday break. Guided by Arias, he designed nucleotide primers at his parents' house, put in orders for reagents amid holiday festivities, and received deliveries at his apartment, because the campus was then closed.

It was no small feat, requiring Aralis to design a test from scratch that could pick up key features that only omicron had, such as the genetic sequences that underlie the variant's significant number of mutations.

"We knew how the genome looked for delta and all the other variants, because of the vast amount of data," he said. Thanks to the collaboration with the local healthcare providers and SBCPHD, he also had access to the new omicron genome.

"The key was to look at these different genomes and compare them to see where there are multiple, significant mutations that would enable the primers to bind to different variants differentially," he said. If these key sections of viral genetic material are present, the commercially synthesized primers would bind to them, initiating a process that exponentially multiplies this genetic material until millions to billions of target DNA



strands are present and detectable by fluorescent probes.

Just after the new year, Aralis had an assay to put to work, a test that could deliver an answer in a few hours, as opposed to the weeks required for genetic-sequencing results.

Even as the assay underwent refinement, it proved immediately useful, first by successfully identifying seven of nine test samples as positive for omicron, and later confirming 25 positive omicron cases out of 28 samples provided by County Public Health and Pacific Diagnostic Laboratories. Though the state's data had not shown it at the time, the results indicated that omicron had already gained a foothold in the community.

"We clinicians have been making our best guesses based on indirect evidence and theory, and doing the best we can," Fitzgibbons said. "But Zach gave us an anchor and the knowledge we needed." Thanks to the new assay, she added, local physicians who had been wondering if they should use the other two more readily available monoclonal antibody treatments, REGEN-COV and BAM-ETE, had increasing confidence to forgo them.

Looking at the future beyond omicron, Feinstein said, "This could be used as a starting point in combatting the next problematic variant that comes along."

Meanwhile, in the wake of this success, Aralis remains poised and ready to jump into the next phase of the arms race between virus and human, saying, "We've got a kind of pipeline for doing this now if a new, aggressive variant appears."

> "EVEN AS THE ASSAY UNDERWENT REFINEMENT, IT PROVED IMMEDIATELY USEFUL, FIRST IDENTIFYING SEVEN OF NINE TEST SAMPLES AS POSITIVE FOR OMICRON, AND LATER CONFIRMING 25 POSITIVE OMICRON CASES OUT OF 28 SAMPLES."

DIALING UP A RAPID COVID TEST

COVID testing — having enough tests, while making them fast, affordable, and accurate — has been a huge hurdle throughout the pandemic, and especially during periods of rapidly increasing cases, when testing is most needed. Recently, in a potential game changer for COVID-19 pandemic control efforts, a new cell phone app and lab kit were developed that can transform a smartphone into a COVID-19 (and flu) detection system.

The system's test is among the most rapid, sensitive, affordable, and scalable known, and it can be readily adapted for other pathogens having pandemic potential. It also provides a platform for inexpensive home-based testing. Developed by a research team of UC Santa Barbara scientists and Santa Barbara Cottage Hospital scientists and physicians, the app was described in an article titled "Assessment of a Smartphone-based Loop-mediated Isothermal Amplification Assay for Detection of SARS-CoV-2 and Influenza Viruses," and published in the January 2022 issue of the journal *JAMA Network Open*.

The app uses a smartphone's camera to measure a chemical reaction containing a chemical dye that fluoresces when the virus is amplified — the more glow, the more virus is present — and determines a diagnosis in 25 minutes, at a fraction of the cost of current diagnostic methods and with accuracy matching that of PCR tests, with the result ready in a fraction of the time. Free and available to all, both the app and the methodology were developed by UCSB professors **Michael Mahan, David Low,** and **Charles Samuel,** along with Santa Barbara Cottage Hospital physicians Jeffrey Fried, M.D., (UCSB alumna) **Lynn Fitzgibbons, M.D.,** and additional collaborators at both UCSB and Santa Barbara Cottage Hospital.

"As new COVID variants emerge globally, testing and detection remain essential to pandemic control efforts," said Mahan, lead author on the paper. "Nearly half the world's population has a smartphone, and we believe that this holds exciting potential to provide equal access to precision diagnostic medicine."

The collaboration was launched to develop rapid, low-cost diagnostics that can be used by healthcare providers anywhere in the world to diagnose COVID-19. The kit can be produced for less than $100 and requires little more than a smartphone, a hot plate, and LED lights. The screening tests can be run for less than $7 each versus $10 to $20 per rapid antigen test and $100 to $150 per PCR test. The so-called LAMP tests match the sensitivity and accuracy of the gold-standard PCR test at a fraction of the time and cost. Further, LAMP occurs at constant temperature, which is suitable for point-of-care and home-based testing.

The process, termed smaRT-LAMP, is simple and straightforward. To use the kit, a small amount of a person's saliva is collected in a cup, put onto a hot plate, and then analyzed by the smartphone app using the phone's camera and the diagnostic kit. Twenty-five minutes later, the app shows a green button for a negative result and a red button for a positive one. No additional special materials are required.

"The key finding was solving the problem of false positives resulting from the high sensitivity of the LAMP systems, something scientists have struggled with for more than twenty years," UCSB collaborating scientist **Douglas Heithoff** explained. "It took more than five hundred attempts to solve it for COVID-19, after which flu viruses were detected on the very first try."

The simple lab test can detect and differentiate COVID-19 and the flu, which show very similar respiratory disease symptoms, making misdiagnosis common.

"Rapid and affordable point-of-care testing is critically important for underserved communities around the world, many of which are struggling with inadequate diagnostic testing access and limited laboratory infrastructure," explained Fitzgibbons, who is an infectious-disease physician.

"We hope technologies like this offer new ways of bringing state-of-the-art diagnostics to underserved and vulnerable populations," Low explained.

"Such early detection and quarantine can also reduce the risk of future global outbreaks," added Fried, a critical-care physician.

This research was funded by grants from the National Institutes of Health's National Heart, Lung, and Blood Institute, Santa Barbara Cottage Hospital, and U.S. Army Combat Capabilities Development Command's Army Research Laboratory via the Institute for Collaborative Biotechnologies cooperative agreement and contract.

In New Book, TM Professor Aims to Help Companies Thrive in the Digital Era

The digital revolution is here, and it's here to stay, which causes some people to fear that they will need to master exotic new skills to survive. In a new book, *The Digital Mindset: What It Really Takes to Thrive in the Age of Data, Algorithms, and AI*, **Paul Leonardi,** a professor in the Department of Technology Management, and his co-author, Tsedal Neeley, a business administration professor at the Harvard Business School, argue that, to succeed in the digital era, people must learn to see, think, and act in new ways. The authors provide three approaches to enable senior leaders and their employees to develop the necessary digital skills.

For nearly twenty years, Leonardi has focused his research on how organizations can innovate and create the change that will improve the work of management and team members. He has published more than sixty articles in top academic journals and is an elected fellow of the International Communication Association.


Paul Leonardi offers guidance for prospering in the digital age.

Convergence: *Let's start with the title — what is a digital mindset, and why is it so important for people to develop?*

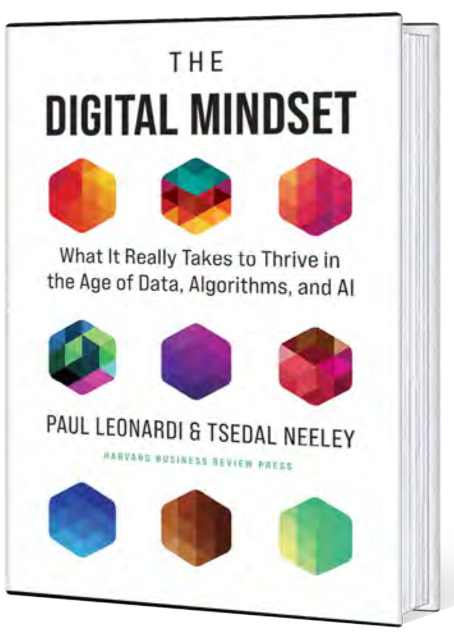
PL: When we talk about the digital transformation of companies, many people think that they need to develop lots of complex new skills, such as learning to code in the Python language, or multinomial regression. What we have found by working with companies over the past two decades is that, sure, success in the digital age requires some new skills, but more importantly, it requires new ways of thinking and acting to take advantage of the new possibilities that are available. That's what a digital mindset really is, and we have identified three approaches to help people meet the challenge of the digital age.

C: *What are those approaches and actions?*
PL: We argue that a digital mindset consists of approaches to collaboration, computation, and change. Most people already have in their minds an approach toward collaboration. They know what it means to work with others, and they have a sense, even when working remotely, of what good collaboration looks like. A huge part of collaboration in the digital era is knowing how to work effectively not just with other people, but also with machines. How do you know whether you can trust the predictions the machine is giving you, or how do you give commands to get machines to do what you want them to do?

Most people wouldn't say that they have an approach to computation. But in the digital age, they need one. Computation is about working with data. One of our big points in the book is that data aren't collected, they are *produced*. All data are social constructs; they are neither natural nor neutral. We're in a world where decisions are based increasingly on data. All you have to do is think about the ads you get served when you're searching on Google, which are happening because of really fine-grained machine learning algorithms. That data is constantly being turned into predictions about what it is we're likely to buy at any moment. To understand whether a business can act on a prediction or a prediction is going to be useful, we need to have some rudimentary statistical knowledge. Interpreting statistics and asking the right questions related to them have to be part of your approach to computation.

The final approach needed to develop a digital mindset is what we call an *approach to change*. Most people think of change as episodic, that we go through long periods of stasis that are punctuated by short episodes of change. But in the digital world, we don't have periods of stasis anymore. We're in a constant process of change which, in the book, we call the process of *transitioning*. We're always transitioning from one set of practices or business models to the next, and that's in large part because of all the new data that are being collected and produced and analyzed through digital technologies. And because we're in this constant process of change, it's extremely important to develop an ethos of experimentation and to get feedback on what's working and what's not. We also need to be sure that leaders of an organization are constantly helping employees develop the skills they need to embrace all of this change, and that those leaders are creating a culture that's receptive to change and not looking forward to a time when things calm down — because they won't.

C: *Your book discusses the thirty-percent rule. Can you tell us about that?*
PL: To many of us, the idea of being a competent digital person is kind of scary, because we think we don't have the necessary skillset. But we have found that to be a competent citizen in the digital world requires really only about thirty percent fluency in a number of areas that we outline. I like the analogy of learning a foreign language. Research shows that to communicate at a fluent level in a workplace, you'll need about twelve thousand words. But if you just want to be competent enough to work with people who speak a different language than you do, you need only about four thousand words, about thirty percent of the total. I see that analogy as helpful for thinking about where we are in the digital economy. The book is designed to help give people that thirty percent.



The Digital Mindset *will be released May 10 and will be available at bookstores and online retailers.*

C: *How do you make these technical fields, which can be intimidating, less daunting and more understandable to the reader?*
PL: One key is to use very basic language to help people grasp things. There are some technical terms for sure, but the writing is really aimed at teaching you what you need to know about a topic to make sense of the data that will be thrown at you all the time in decision-making situations.

C: *How did you and Tsedal Neeley connect and start collaborating on this book?*
PL: She and I are long-time collaborators; we joke that we are academic siblings. We never planned to write this book, but in our teaching, consulting, and speaking gigs, we both kept hearing the same thing over and over again, which is, "If I'm going to make a digital change happen in my organization, then all of my employees are going to need to be digitally competent, and I'm not sure how to do that." That's what really compelled us to write the book that no one else was writing.

C: *Can you tell me a little about what was involved in researching the book?*
PL: We've interviewed more than three thousand people, we've surveyed upwards of five thousand people, and we've spent hundreds of hours observing people using digital technologies in the workplace. A big part of our strategy was to try to look at people having a wide variety of digital skills and competencies across a number of different industries at various career stages, and identify people in all of these different areas who have developed a digital mindset. From there, we were able to extract the thirty percent necessary to have a digital mindset.

C: *You have published academic books and many journal papers. Can you talk about how this book is different?*
PL: The goal of this book is to translate that academic research for a wider audience so they can develop a set of practical skills. It's the first book I've written for a wider audience. My big fear is that an expert can look at each chapter and say that we barely scratched the surface, because in the academic books and articles I've written, I go all the way to the bottom every time. But in trying to create a helpful guide for a broader audience, my goal is different: It's about getting the reader to that thirty percent and explaining things in ways that they are going to understand.

C: *What do you hope your readers get out of this book?*

“That's really what a digital mindset is all about. It's about understanding opportunities for change by having an ability to appreciate the underlying engineering and science.”

PL: Three things. The first is confidence. I hope that after reading the book, they'll be able to say "I can do this." They will know they are prepared to be a key player in helping their company move into the digital age. The second thing is an awareness that they have developed new knowledge and an understanding of where they need to gain more knowledge and training to be effective in their role today and in where they want to go in their careers tomorrow. The third thing is for them to see more possibilities and more avenues for themselves and their companies.

C: *This book exemplifies the relevance and importance of UCSB's Technology Management. What do you think it says about the department and its faculty and research?*
PL: Recently, we officially became the Department of Technology Management and are now the sixth department in the College of Engineering. What we do in technology management is to provide a bridge between engineering and the world of work. If you don't have the right mindset, you're not going to be able to see how we can take those technologies that are being developed in the college's other five departments and make the right kind of organizational changes to make those technologies effective. That's really what a digital mindset is all about. It's about understanding opportunities for change by having an ability to appreciate the underlying engineering and science. As a department, Technology Management helps people understand how to make the organizational changes that allow them to effectively utilize and implement emerging technologies, while also identifying the kinds of organizations that are able to develop and apply the technologies that are being developed at great research universities like USCB.

FACULTY AWARDS AND RECOGNITIONS

JUNE 2021 – MARCH 2022

UC Santa Barbara College of Engineering faculty receive many of the most prestigious awards and honors bestowed by academic and professional societies in recognition of their leading-edge research and contributions to their fields. Here are some of the faculty who were recognized by their peers between June 2021 and March 2022.

MAHDI ABU-OMAR

Professor, Chemical Engineering, Mellichamp Chair of Green Chemistry

Affordable Green Chemistry Award; American Chemical Society
The award recognizes a chemist for outstanding scientific discoveries of eco-friendly chemistries that may enable less-expensive products or manufacturing processes. Abu-Omar's group focuses on solving the growing plastics waste problem by investigating novel ways to reuse plastics, and working to create the science that can provide renewable and recyclable alternatives to traditional petrochemical-based materials.

CHRISTOPHER BATES

Assistant Professor, Materials, Chemical Engineering

Rising Star in Polymers in 2021, *ACS Polymers Au*
Bates was one of thirteen early-career polymer scientists named Rising Stars in Polymers and invited to submit a peer-reviewed paper for a special issue of *ACS Polymers Au*, the open-access journal of the American Chemical Society. His paper discussed a new class of super-soft conductive elastomers that he and collaborators developed by leveraging a highly branched bottlebrush polymer architecture. Their findings will be useful in applications where both softness and conductivity are valuable, such as wearable electronics

JOHN BOWERS

Distinguished Professor, Materials, Electrical and Computer Engineering; Kavli Professor of Nanotechnology

Elected Fellow, American Association for the Advancement of Science; Highly Cited Researchers List, Clarivate Analytics
Bowers was recognized by the AAAS for his "pioneering research in silicon photonics, including hybrid silicon lasers, photonic integrated circuits, and ultra-low-loss waveguides. A world-leading researcher in the areas of silicon photonics, optoelectronics, energy efficiency, and the development of novel low-power optoelectronic devices, Bowers was also recognized among the top one percent of his field based on the number of times his published papers have been cited by peers.

JAMES BUCKWALTER

Professor, Electrical and Computer Engineering

Elected Fellow, Institute of Electrical and Electronics Engineers
The IEEE Board of Directors elevated Buckwalter's status to the grade of Fellow in recognition of his "contributions to high-efficiency millimeter-wave power amplifiers and optical transceivers in silicon-on-insulator (SOI) technologies.

KEREM CAMSARI

Assistant Professor, Electrical and Computer Engineering

Young Investigator Award, Office of Naval Research
Camsari was one of thirty-two junior faculty selected to receive the prestigious award. He will receive a three-year, $510,000 grant in support of his work to design a probabilistic computer to solve computational problems faster and more efficiently. His work could address problems such as supply-chain logistics, traffic optimization, tactical communications, and probabilistic-decision making.

PHILLIP CHRISTOPHER

Professor, Chemical Engineering; Mellichamp Chair of Sustainable Manufacturing

Ipatieff Prize, American Chemical Society
Christopher received the triennial national award that recognizes an individual under the age of forty for outstanding chemical experimental work in the field of catalysis or high pressure. Christopher's research group builds and designs reactors and uses light, spectroscopy, and microscopy to probe the structure and function of catalysts in order to gain molecular-level insights that enable the design of more sustainable materials and more environmentally friendly catalytic processes.

RAPHAËLE CLÉMENT

Assistant Professor, Materials

Early CAREER Award, National Science Foundation
Clément received the foundation's most prestigious award given to early-career faculty in support of her work to investigate new materials for sodium-ion batteries. Her work could eliminate issues of toxicity, raw materials supply, and cost that plague current lithium-ion batteries. For more on her project, see page 14.

XI DAI

Professor, Materials

Highly Cited Researchers List, Clarivate Analytics
A leading expert in the theory of quantum materials, Dai was identified among the top one percent of his field based on citations. Scientists on the annual list have demonstrated significant and broad influence in their research areas, reflected in their publication of multiple papers that were highly cited by their peers over the past decade.

SAMANTHA DALY

Professor, Mechanical Engineering

Elected Fellow, American Society of Mechanical Engineers
Daly was elected in recognition of significant engineering achievements. Her research group specializes in the application of experimental mechanics to materials science in an effort to characterize, design, and develop advanced materials.

UMESH MISHRA

Donald W. Whittier Distinguished Professor, Electrical and Computer Engineering

Jun-ichi Nishizawa Medal, Institute of Electrical and Electronics Engineers
Mishra was recognized for his "contributions to the development of gallium-based electronics." The medal is awarded annually to one individual in the fields of materials science and device technologies.

STEVEN DENBAARS

Mitsubishi Distinguished Professor of Materials and Electrical and Computer Engineering

AAAFM-Nakamura Award, American Association for Advances in Functional Materials
DenBaars was recognized for his pioneering work with gallium nitride (GaN), a highly efficient and high-performing semiconductor material that is the foundation of energy-efficient lighting, micro-LED displays, power electronics, and laser diodes. The honor was given to an outstanding scientist in the field of functional materials who has made significant contributions and whose work shows significant innovation in the field.

GALAN MOODY

Assistant Professor, Electrical and Computer Engineering

Research Award, Cisco Research
The research award will allow Moody to work with Cisco's new Quantum Research team to design, fabricate, and test prototype devices that use a photon as an optical qubit to encode quantum information. The collaboration allows Moody to transition from fundamental research to engineering and developing quantum technologies that could eventually lead to commercialization.

YUFEI DING

Assistant Professor, Computer Science

Research Award, Cisco
With support from Cisco, Ding will pursue novel quantum computing research activities from a programming system perspective. Her analysis of optimization problems in quantum circuit distribution could help researchers build a network of connected quantum devices.

JOHN HARTER

Assistant Professor, Materials

Early CAREER Award, National Science Foundation; Faculty Fellowship, Hellman Family Fellowship Foundation
Harter received the prestigious Early CAREER Award to conduct experimental research on a special type of superconductivity called odd-parity superconductivity. His work could have far-reaching consequences for quantum technology.

PAUL LEONARDI

Duca Family Professor, Technology Management

Elected Fellow, International Communication Association
Leonardi was elected in recognition of distinguished scholarly contributions to the broad field of communication. His research is focused on how companies can design their organizational networks and implement new technologies to more effectively create and share knowledge. (For more on his new book, see page 38.)

LEI LI

Assistant Professor, Computer Science

Best Paper Award, Association of Computational Linguistics
Li and his co-authors received the best paper award out of 3,350 submissions to ACL, the leading conference on NLP. The paper explores an optimal and efficient vocabulary learning algorithm, VOLT, for improved performance in machine translation.

SHUJI NAKAMURA

Distinguished Professor, Materials, Electrical and Computer Engineering ; Cree Professor of Solid State Lighting and Displays

Richard J. Goldstein Energy Lecture Award, American Society of Mechanical Engineers
The award recognizes the Nobel Laureate for his "transformational innovation in energy-conserving electronic and photonic materials, particularly pioneering work in light emitters based on wide-bandgap semiconductors and the invention of efficient blue-light emitting diodes that have rendered substantive bright and energy-saving white light sources".

IGOR MEZIĆ

Professor, Mechanical Engineering

Elected Fellow, Institute of Electrical and Electronics Engineers
Mezić was honored by the IEEE for his "contributions to modeling and control using Koopman operator techniques." The Koopman operator theory is a sophisticated mathematical approach of using data-driven analysis of nonlinear flows to understand and forecast dynamical systems.

MICHELLE O'MALLEY

Professor, Chemical Engineering

Allan P. Colburn Award for Excellence in Publications, American Institute of Chemical Engineers
The award is presented to a young scientist who made significant contributions to chemical engineering through publications. O'Malley was honored for "engineering unusual microorganisms from nature for biomass deconstruction and novel bioprocessing." Her research set the foundation for engineering microbial interactions in anaerobes to accelerate biomass breakdown and investigate how microbes partner in nature and bioreactors.

NELSON PHILLIPS

Professor, Technology Management

Elected Fellow, Academy of Management
Phillips was honored for his significant contributions to the science and practice of management. As an organizational theorist, Phillips focuses his research on how humans organize, and particularly, how people and technology come together in organizations.

TRESA POLLOCK

Interim Dean and Alcoa Distinguished Professor, Materials

Elected Honorary Member, French Society of Metallurgy and Materials
Pollock received the title of Honorary Member in recognition of her outstanding services in metallurgy and materials. Her recent research has been focused on developing a femtosecond laser-aided 3-D tomography technique, damage detection and modeling by resonant ultrasound spectroscopy, thermal barrier coatings systems, new intermetallic-containing cobalt-base materials, nickel-based alloys for turbine engines, and lightweight magnesium alloys.

TIMOTHY SHERWOOD

Professor, Computer Science

Elected Fellow, Institute of Electrical and Electronics Engineers; Research Highlight Award, Communications of Association of Computing Machinery
Sherwood was elected a fellow for his "contributions to computer system security and performance analysis." An article that he co-wrote with **Dmitri Strukov** (see below) and other colleagues was also featured by ACM. Only two papers out of all computer architecture publications are selected each year for this award. Sherwood develops novel high-throughput hardware and software methods to monitor and analyze systems. Such techniques offer critical insight on performance anomalies, energy efficiency, and software bugs.

DMITRI STRUKOV

Professor, Computer Science

Research Highlight Award, Communications of Association of Computing Machinery
An article that Strukov co-wrote with **Timothy Sherwood** (see above) and other colleagues was selected for a Research Highlight Award by ACM. Only two papers out of all computer architecture publications are selected each year for this award. In the paper, researchers discuss the natural relationship between modern decision-tree algorithms and new advances in race logic, demonstrate extremely energy-efficient classification, and generate excitement around broader in-sensor processing applications.

CHRIS VAN DE WALLE

Professor, Materials ; Kroemer Professor of Materials Science

Highly Cited Researchers List, Clarivate Analytic
This was the fifth straight year that Van de Walle earned a spot on the annual list that identifies scientists who are in the top one percent of their field by citations. They have demonstrated significant and broad influence in their fields, which is reflected in their publication of multiple papers that were highly cited by their peers over the past decade.

ZHENG ZHANG

Assistant Professor, Electrical and Computer Engineering

Ernest S. Kuh Early Career Award, IEEE Council on Electronic Design Automation
Zhang was honored for his "contributions towards fundamental stochastic computation methods for circuit simulation and testing beyond." The annual award recognizes a junior faculty member who has made substantial contributions to the area of electronic design automation.

YANGYING ZHU

Assistant Professor, Mechanical Engineering

Pi Tau Sigma Gold Medal, American Society of Mechanical Engineers
The annual award celebrates one individual's outstanding contributions to mechanical engineering within the first ten years of earning a bachelor's degree. Zhu's research focuses on using thermo-fluid engineering approaches to address challenges in energy storage, thermal management of electronics, water harvesting, and transmittance of respiratory diseases.

FUN FACT

#1 public university in percentage of eligible junior faculty who received NSF Early CAREER Awards from 2016-'21.

AWARD-WINNING COE STUDENTS AND POSTDOCTORAL RESEARCHERS

JUNE 2021 – MARCH 2022

Numerous undergraduate and graduate students, as well as postdoctoral scholars in the College of Engineering have received national recognition for their work while in pursuit of discovery. Recently, eleven engineering students were offered prestigious graduate research fellowships from the National Science Foundation, a distinction that provides three years of financial support, totaling $138,000 apiece. The Graduate Research Fellowship Program is the nation's oldest fellowship program that recognizes and supports outstanding graduate students pursuing research-based graduate degrees in STEM disciplines. Here is a look at some additional awards received by COE students and postdocs between June '21 and March '22.

SHAIMAA AZZAM
Postdoctoral Researcher, Electrical and Computer Engineering
Advised by Galan Moody

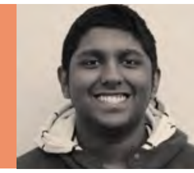
Participant, EECS Rising Stars Workshop

DHEERAJ BABY
PhD Student, Computer Science
Advised by Yu-Xiang Wang

Best Student Paper, Conference on Learning Theory

JUAN CHAMORRO
Postdoctoral Fellow, Materials
Advised by Stephen Wilson and Ram Seshadri

MPS-Ascend Fellowship, National Science Foundation



SANJAY CHANDRASEKARAN
PhD Student, Computer Science
Advised by Arpit Gupta

Research Fellowship, M-Lab

MARISSA GIONET-GONZALES
Postdoctoral Researcher, Mechanical Engineering
Advised by Beth Pruitt and Ryan Stowers

eFellow, NSF/ASEE; President's Postdoctoral Fellowship, Univ. of California

SAMHITA HONNAVALLI
Undergraduate, Computer Science
Advised by William Wang and Diba Mirza

Outstanding Researchers Award Honorable Mention, Computing Research Association

GYUWAN KIM
PhD Student, Computer Science
Advised by William Wang

Best Paper Award, Simple and Efficient NLP Workshop

SHARON LEVY
PhD Student, Computer Science
Advised by William Wang

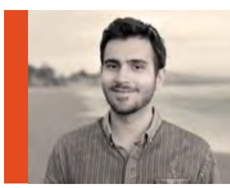
Research Fellowship, Amazon

SUJAYA MAIYYA
PhD Student, Computer Science
Advised by Amr El Abbadi and Divyakant Agrawal

Participant, EECS Rising Stars Workshop

AESHA PAREKH
Undergraduate, Computer Science
Advised by William Wang and Diba Mirza

Outstanding Researchers Award Finalist, Computing Research Association



KAMYAR PARTO
PhD Student, Electrical and Computer Engineering
Advised by Kaustav Banerjee and Galan Moody

Graduate Student Research Fellowship, Department of Energy

SHLOMI STEINBERG
PhD Student, Computer Science
Advised by Lingqi Yang

Graduate Research Fellowship, NVIDIA

TIANQI TANG
PhD Student, Electrical and Computer Engineering
Advised by Yuan Xie

Participant, EECS Rising Stars Workshop

VIRGILE THIÉVENAZ
Postdoctoral Scholar, Mechanical Engineering
Advised by Alban Sauret

Milton Van Dyke Award, American Physical Society

YUKE WANG
PhD Student, Computer Science
Advised by Yufei Ding

Graduate Fellowship, NVIDIA

ELI ZOGHLIN
PhD Student, Materials
Advised by Stephen Wilson

Graduate Student Research Fellowship, Department of Energy

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To learn more about opportunities for the College of Engineering and the Division of Math, Life and Physical Sciences, please contact
Lynn Hawks, Senior Assistant Dean of Development.
805-893-5132 / lynn.hawks@ucsb.edu