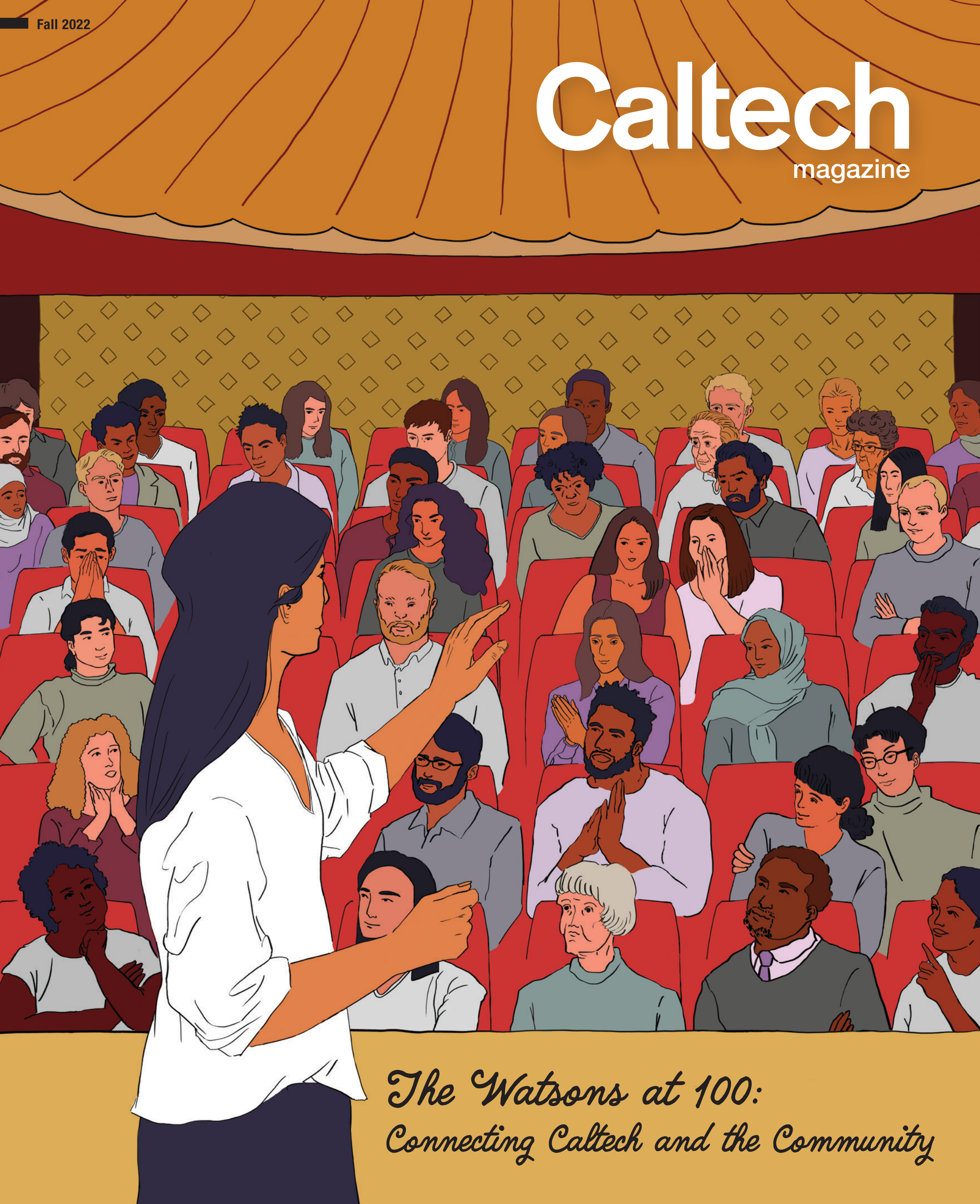
Fall 2022

Caltech magazine



The Watsons at 100: Connecting Caltech and the Community

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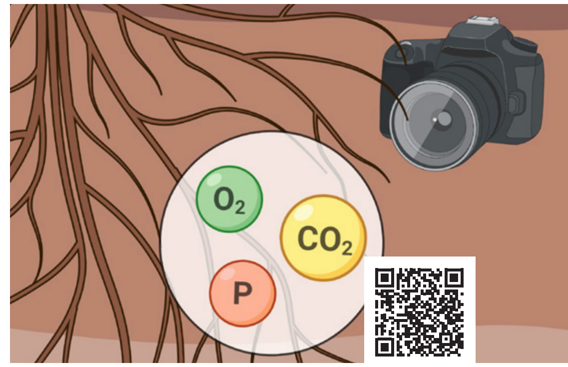

A Competitive Culture
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To Boldly Build
Article: **Caltech’s Lego-loving astronomer**

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Fall 2022 Volume LXXXV, Number 3

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Above: Nick Scoville's dog, Luna, relaxes next to handmade chairs crafted by her owner. See story on **page 6.**

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Letters

"Writing" Kudos

Whitney Clavin's fascinating essay "Writing in the Language of Math" explores several innovative modes of expression in mathematics. Another example is Leonardo's depiction of the formula for the volume of a dodecahedron in a sketch: dissected into 12 pentagonal pyramids, in turn into 60 tetrahedra, and reassembled into a figure of known volume (Codex Forster 1, folio 7r, Fritjof Capra, *The Science of Leonardo*). In the digital age, writing tools such as LaTex can be used to even do algebra: copy the previous equation; make a small legitimate change; repeat. Then I am tempted to replace the dozens of intermediate steps with "trivial algebraic manipulation yields" for the final publication. Perhaps even more innovative ways of writing math can spring out of Fritz Zwicky's morphological box applied to this topic.

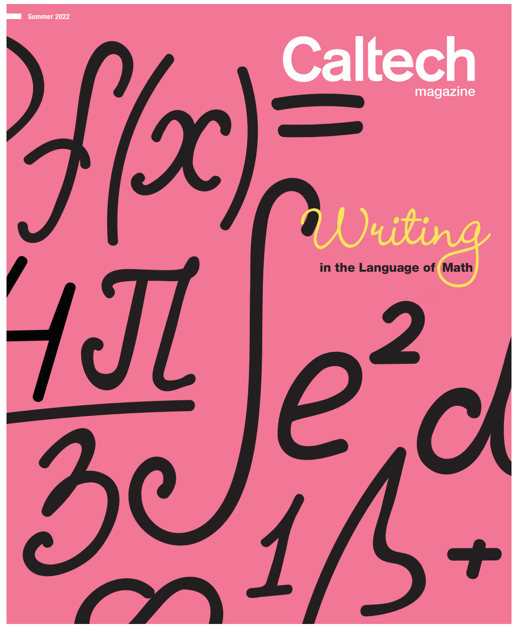
Jeff Scargle (PhD '68)
MENLO PARK, CA

Just wanted to tell you how much I appreciate your work to help us understand cutting-edge science fields outside of our own—particularly MATH. Math was a real problem at CIT my second year—nearly flunked it. Yet as an orthopaedic surgeon specializing in spine matters for over 40 years, I have recently ventured somewhat tentatively into largely mathematical analyses (elementary stuff, really) of aviation crash issues in night approaches to so-called black hole airports! How the h--- did that happen? Caltech to me was truly a small cozy incubator, with cross-fertilization a primary feature!

Robert C. Thompson, MD (BS '60)
HOMER, AK

Great article! I wonder if young folks nowadays know where the term "Carriage Return" comes from that lives on as ASCII character no. 13. Probably they think of bringing back a rental car 😆

Thomas Schnuerer on Twitter



A Star Is Born

Thank you, Philip Appleton, for the brilliant, lucid, thrilling explanation of this remarkable image and extension of human awareness. I have been a lifelong student of astronomy and astrophysics. The data from JWST is reawakening a keen passion in my mind to continue that journey of exploration. Having wonderful teachers and scientists to help the public see what they see in the data, is essential. Philip, I hope you do a lot more of these videos showing the discoveries of JWST; even about subjects other than Stephan's Quintet. ... I have to tell you that watching this video was enlivening ... I have thrills and chills running up and down my spine. ... Thank you!

Joseph Woodhouse on YouTube

See the YouTube video "Stephan's Quintet: Caltech Expert Gives a Guided Tour of the New JWST Image," and also the story on page 4.

For the Record

The obituary for Carl V. Larson in the Summer 2022 issue's "In Memoriam" section incorrectly stated Larson's birth year. He was born in 1930.

Caltech
Instagram

Endnotes Sneak Peek

This year, the Earnest C. Watson Lecture Series turns 100. If you were to give a Watson Lecture, what would the title be, and why should people attend?

"You Can Lead a Horse..."

People should attend to learn about the behavioral psychology and economics that leads nations and their leadership into wars—both consequential and relatively trivial. Careful analysis and the application of game theory in deconstructing modern and historical wars, including civil war, sheds light on the opportunities missed in avoiding the worst consequences and provides a basis for understanding the contemporary political movements shaping our futures.

Mark Caruso (BS '83)
PALM DESERT, CA

For more Watson Lecture ideas, see Endnotes on **page 40.**

SoCaltech

- Grant D. Venerable House celebrates a new era
- Hustle and bustle as students return to campus
- Tales of Caltech's trees

Collision Course

Staff scientist Philip Appleton has spent the last 18 years studying Stephan's Quintet, a grouping of five galaxies made famous as heaven in *It's a Wonderful Life* (directed by Frank Capra, BS 1918). So when the first batch of long-awaited, jaw-dropping images from NASA's new James Webb Space Telescope (JWST) included a new mosaic of the quintet, it was a windfall for Appleton and his colleagues at Caltech's IPAC astronomy center. The team has studied this turbulent region with instruments such as the now-retired Spitzer Space Telescope, whose data archive is based at IPAC. (Spitzer was managed by JPL; Caltech manages JPL for NASA.)

Upon release of the composite view, made possible by infrared vision and constructed from almost 1,000 separate image files, Appleton recorded a video discussing why the new picture will lead to a better understanding of galactic evolution and stellar birth.

"What's fascinating about Stephan's Quintet is that all these galaxies are crunched together in a very small area of space," he said. "Imagine our own Milky Way system, which is a giant pinwheel of rotating gas and dust. The nearest galaxy to us is the Andromeda Galaxy, which is faint, fuzzy in our own sky when we look up there. But the Stephan's Quintet … these galaxies are very, very close, within almost one-tenth of the distance between our own Milky Way and the Andromeda. As a result of that, they tend to be smashing into each other and colliding and producing what we call tides, just like you have tides on Earth, except that in galaxies, tides cause these long tails to be produced when galaxies pass by each other very closely. This is a beautiful example of that."

To watch the video, visit: magazine.caltech.edu/post/quintet

"We have to do everything we can to convince people that in the United States elections are in fact being run freely and fairly and that they're free from fraud. That's a tall order for one faculty member at Caltech. But it is the sort of thing that here at Caltech we can do to help and that election scientists throughout the country are going to be doing in this election cycle and in the future to try to help turn this around."

Michael Alvarez, *professor of political and computational social science, speaking ahead of the 2022 midterm election about the role of election scientists in combating misinformation.*

A Matter of Scale

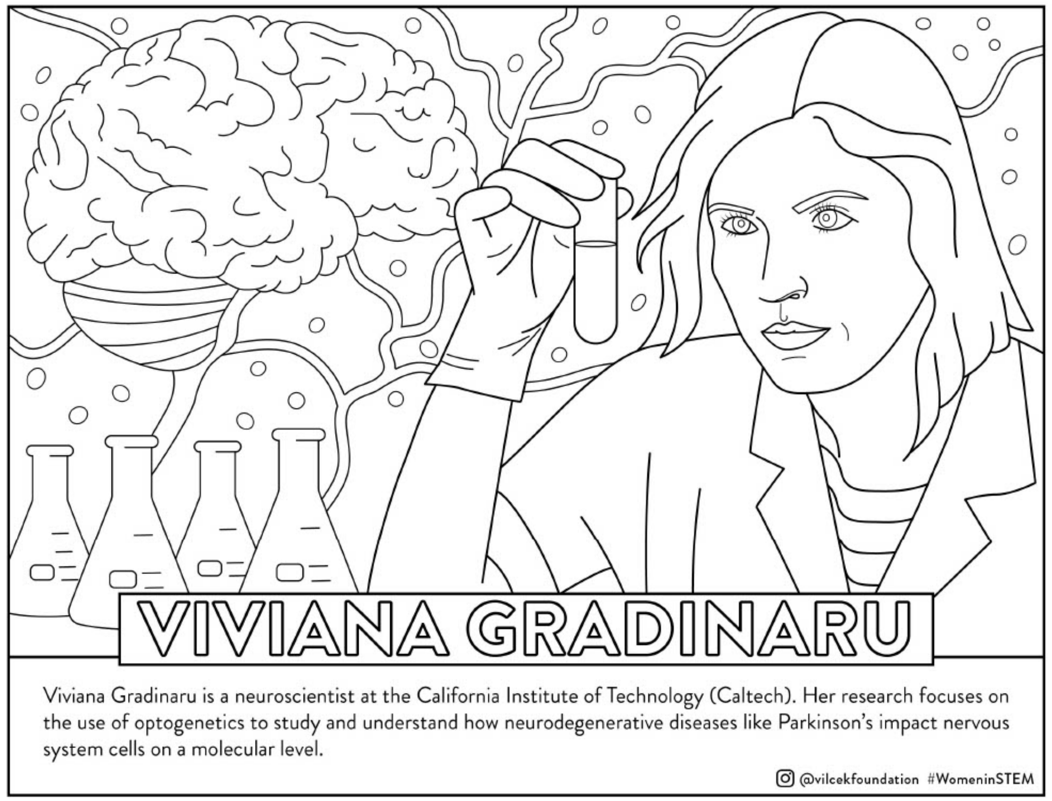
Nick Scoville, Francis L. Moseley Professor of Astronomy, Emeritus, has devoted more time to art projects since his retirement in 2016. Some of his projects include hanging tables, sculptural pot racks, and most recently, a large hanging fish. Scoville used sheets of perforated aluminum to create the fish mobile, which hangs among the trees outside his house atop Mount Washington near Highland Park. The metal sheets were laid out in such a way to create an interference, or moiré, pattern that shifts as the mobile moves in the sunlight and makes the material look like fish scales. Scoville, who joined the Caltech faculty in 1984, has been a sculptor for most of his career. "With science, I like to use my brain to figure things out; with art I like to start with a completely blank slate," he says. In both cases, his overarching goal is to come up with "something new and completely different."

New Namesake

The Caltech community gathered on the Olive Walk for the dedication of the Grant D. Venerable House on October 21, 2022. The undergraduate student residence was named in fall 2021 in honor of the late alumnus, who was the first Black student to graduate from Caltech as well as an active student leader and athlete during his time on campus. Venerable's children—Grant D. Venerable II, Lynda Venerable Ellington, and Lloyd Venerable—addressed the crowd. His daughter, Venerable Ellington, said, "When my older brother called me a number of months ago and told me that this was going to take place, I think I spent the next few days in joyous tears, truly."

Read more about the event:

STEM in Color



Viviana Gradinaru (BS '05), a Caltech professor of neuroscience and biological engineering and director of the Center for Molecular and Cellular Neuroscience, is included in a coloring book called ***Think Like a Girl: A Coloring Book of Women Pioneers in STEM***, which was published by the Vilcek Foundation in February 2021. All of the women featured in the book are immigrants to the United States who have been recognized by the foundation. Gradinaru, who was born in Romania, received the 2020 Vilcek Prize for Creative Promise in Biomedical Science.

Send a photo of your—or your kids'—colored-in picture to **magazine@caltech.edu**, and we might just publish it in our next issue.

Download the book:

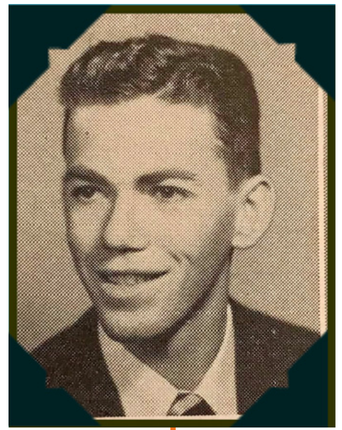
SQUARE ROOTS

Nobel Laureate Barry Barish now has a physical place in history to accompany his place in physics history. In May 2022, the Los Angeles City Council dedicated the intersection of Aloha and St. George streets, adjacent to John Marshall High School in the neighborhood of Los Feliz, as Dr. Barry Barish Square in honor of the physicist who graduated from the school in 1954.

Barish, the Ronald and Maxine Linde Professor of Physics, Emeritus, shared the 2017 Nobel Prize in Physics with his Caltech colleague Kip S. Thorne (BS '62), the Richard P. Feynman Professor of Theoretical Physics, Emeritus, at Caltech, and MIT's Rainer Weiss, for their contributions to the Laser Interferometer Gravitational-wave Observatory (LIGO) and the direct observation of gravitational waves. LIGO is supported by the National Science Foundation and operated by Caltech and MIT.

Barish, who also attended Micheltorena Elementary and Thomas Starr King Middle schools in Los Angeles, says he is honored by the gesture and that his experience at Marshall was transformative.

"During my time at Marshall, I 'discovered' advanced math and modern science, and that period set me on a path toward a long career in physics," Barish says. "I am an example of a kid who was educated and found his way through the public education system in the U.S. We should treasure and nurture it as an essential part of what makes America special."



Facing page: Barish (right) with Gary Garcia, principal of John Marshall High School. Left: High School portrait, winter class of '54.

Caltech in Five Trees

Bryan Vejar, Caltech's arborist for the last three years and founder of the Caltech Tree Corps, wants to educate the public about the power of trees, so people can soak in the grandeur around them. Here, Vejar describes five species across campus that tell the story of Caltech's treescape:

"There is the concept called 'plant blindness,'" says Vejar, who performs daily maintenance with his team on the Institute's living collection, which includes some 3,400 trees in and around campus and faculty housing. "You can be walking under the trees but not even notice them, which is crazy because there are these gigantic, living, dynamic life forms all around us. If there was a giant whale next to you, you'd be saying, 'Oh my God, what an amazing thing.'"

1. Coast Live Oak

The backbone of our native woodlands, the long-lived coast live oak has held watch over our ecosystem since long before Caltech was around. This one shades the picnic tables outside Broad Cafe. A keystone species of cultural and ecological importance, many hundreds of other native species rely upon it for habitat and sustenance. Extra care is taken to help preserve them on campus wherever appropriate. [Tree ID: 2132]

2. Engelmann Oak

The rarest and most threatened of Caltech's native oaks, the venerable Engelmann oak's natural range extends along a narrow strip from Pasadena to San Diego County. Our most famous one, the Founders Tree, grew proudly near Caltech Hall until it died in 2016 and was turned into the long table in the Red Door Marketplace. Few mature specimens, such as this giant in the north court of the George W. Downs Laboratory of Physics and Charles C. Lauritsen Laboratory of High Energy Physics, remain on campus. [Tree ID: 2652]

3. Jacaranda

The jacaranda is native to tropical regions of South America but is ubiquitous across campus and the Los Angeles area because the species is drought tolerant and well adapted to our climate. This particular tree is located outside the Athenaeum. The jacaranda shades walkways with its large fern-like leaves, and it signals the end of the school year with an explosion of purple confetti in mid-to-late spring. [Tree ID: 696]

4. Coast Redwood

Our state tree, the coast redwood has claimed its place as an icon of our environment. Its fibrous bark and splays of flattened needle-like leaves recall images of foggy, towering coastal forests. Though Caltech has many, like this one just outside Powell-Booth Laboratory, they struggle with Southern California's dry summers. For this reason, this magnificent species will be gradually phased out of our urban forest. [Tree ID: 2870]

5. American Sweetgum

The most plentiful tree species on campus, this Eastern and Central American native was once thought to be the perfect tree to import to California. It is one of the few trees here that undergoes a dramatic fall transformation, when its maple-like leaves turn from bright green to striking yellow to fiery reds and deep burgundies. The sweetgum has fallen out of favor because it sheds seed pods (known as ankle breakers), plays host to a variety of invasive pests and diseases, and its shallow roots often lift sidewalks. [Tree ID: 1051]

Vejar has created a map detailing every tree on Caltech's campus. Find each tree above through their ID number:

Sandra O'Neill (fourth-year undergraduate student)

#SoCaltech is an occasional series celebrating the diverse individuals who give Caltech its spirit of excellence, ambition, and ingenuity. Know someone we should profile? Send nominations to magazine@caltech.edu.

Sandra O'Neill co-authored a study published in The Astrophysical Journal Letters *in February 2022 that showed evidence for the tightest-knit supermassive black hole duo observed to date. O'Neill began college as a chemistry major and had planned to work with Brian M. Stoltz, the Victor and Elizabeth Atkins Professor of Chemistry, as part of Caltech's Summer Undergraduate Research Fellowship (SURF) program in 2020. Due to COVID, that project fell through, but she picked up the astronomy project to stay active during the pandemic and began working with Anthony Readhead, Robinson Professor of Astronomy, Emeritus.*

"I was supposed to work in the Stoltz Lab for my SURF after my first year, but I couldn't. I emailed Carol Casey [associate director of student-faculty programs], and she told me, 'We actually got an email this morning from a professor who's looking for someone.' I hadn't taken an astronomy class before that, and I had to suddenly learn a bunch of things really quickly. Everyone in Professor Readhead's lab did an excellent job of guiding me. It could have been easy for me to just get through that first project and then go back to chemistry. This has definitely certified that I want to go into physics or astrophysics.

"I like it because it's similar to something like archeology in that both are quite messy fields. You can do your best to study an isolated system, or something that you pull out of the ground, but there are so many confounding variables that it's hard to understand the exact origins and the relevance. Here, we're also dealing with the past as it's coming to us and trying to understand the universe around us as it tells us about itself."

For more #SoCaltech, go to magazine.caltech.edu/post/Oneill

Welcomed Back

The 2022–23 academic year officially kicked off at the end of September with the first day of instruction. But the Caltech campus began to bustle earlier in the month with the return of staff, faculty, students, and Institute leaders, who came together to greet new and returning undergraduates and graduate students in a series of events, including Convocation, New Student Orientation, welcome dinners, and picnics. Many of these events were held in person for the first time since the beginning of the pandemic, and the celebrations and opportunities to connect with peers and colleagues each attracted hundreds of participants. The first week of classes ended with the TechFest block party on Beckman Mall, which featured food, games, music, and more.

"I always wanted to work on neuroprosthetics because both of my parents have polio, and I feel like it's something that would really help them. So I'm just like, 'Pinch me, this is so surreal!' I'm here, and I'm very excited."

First-year student **Sanvi Pal**

In the Community

Life as a Seismologist

Pasadena and Alhambra high school sophomores and juniors have the chance to shake up their science education as part of the Seismological Laboratory's annual Caltech Earthquake Fellows program, which brought its first cohort to campus earlier this year.

Over their five months in the program, the inaugural 11 students experienced a compressed version of earthquake science research alongside Caltech graduate student mentors. The high school students posed questions, gathered data with individual seismometers, and collaborated in small groups to analyze and interpret findings. The participants presented their research to their mentors, friends, and families on September 17.

Offered in partnership with the Dr. Lucy Jones Center for Science and Society, the program strengthens ties between Caltech and surrounding communities and encourages students, particularly those from underrepresented backgrounds, to pursue scientific careers.

"We are grateful for the robust partnership that [the Pasadena Unified School District] has with Caltech," says Jodi Marchesso, principal of Sierra Madre Elementary School and the district's former STEM specialist. "Because of this partnership, our students have the opportunity to contribute to research that has an impact on science. It is experiences like this that create a connection between classroom learning and the world around us."

The fellowships offer a one-month immersion in seismology on Caltech's campus in the summer, flanked by Saturday sessions in spring and fall. During their month at Caltech, students tour the Seismological Laboratory and the wider campus; attend talks by experts in geophysics, seismology, and disaster preparedness; learn about college and scientific careers; conduct research; assemble a seismometer; and build coding and data visualization skills useful in several fields of study. After they finish the program, participants keep their laptops and seismometers and receive a stipend.

Jimmy Atterholt, a graduate student mentor, helped to craft the program's curriculum and worked with the students, several of whom were performing research for the first time. "In STEM, there is a high concentration of people who come from families full of people with scientific backgrounds. I don't come from one of these families, and I understand what a disadvantage that can be," he says. "I think it's good to have outreach programs to bring students who don't grow up in that environment into the fold and encourage them to do STEM."

—Ann Motrunich

Watch a video about the Earthquake Fellows program:

Reflections on '72

Fifty years later, the first three Black women to enter Caltech as students look back on their experiences.

1972

By Lyndie Chiou (BS '96)

Clockwise from top left: Karen Maples, MD; Deanna Hunt; and Lauretta Carroll.

On a smog-filled weekend in the late summer of 1972, three Black women walked onto the Caltech campus for the first time as students enrolled at the Institute. This milestone came two years after the first female undergraduates were admitted, 17 years after Caltech first awarded a PhD to a woman, and 40 years after the first Black man had received a diploma.

All three women—Karen Maples, MD (BS '76); Deanna Hunt (BS '76); and Lauretta Carroll (BS '77)—had taken different paths to Caltech and, afterward, went on to lead distinct and distinctive lives.

Coming to Caltech

For Maples, the road to Caltech began when she crossed paths with Lee F. Browne, who joined the Institute in 1970 as director of secondary school relations, a role he held for 20 years. (Browne was recognized recently for his contributions to the Institute and the broader community of STEM students with the naming of the Lee F. Browne Dining Hall.) During his tenure, Browne developed several successful outreach programs to encourage students from underrepresented backgrounds to consider careers in science. He traveled tirelessly to cultivate relationships with high school counselors at hundreds of schools throughout California. Maples, who grew up in Berkeley, credits Browne for her decision to apply to the Institute.

"I didn't know about Caltech at all, but he came to Berkeley High and was looking for folks who had an interest in math and science," Maples said. "I was an African American female with good SAT scores, so I was super-recruited. But Lee Browne really promoted Caltech, so I applied and was able to get in."

In a 1999 Caltech oral history, Browne noted that expanding access to and awareness of Caltech and STEM studies for all students was the focus of his job: "I believe that anybody that wanted to do science and mathematics and engineering … should be able to go wherever they wanted to go to school," he said.

Browne's visit piqued Maples's interest in the Institute, but she says money was the deciding factor, and Caltech had made her an attractive offer. "It came down to financial aid more than anything."

For Maples's classmate Hunt, the choice to attend Caltech was simple. "Location, location, location," she says, laughing. The Compton native was accepted to both Caltech and MIT with full-scholarship offers. But Caltech was close to home, which would allow her to remain close to family.

While the women knew they would be the first Black female students to enroll at the Institute, Maples says that the significance of their presence at Caltech did not fully hit her until she walked onto campus.

"It was a culture shock coming from Berkeley, which had a very vibrant community. Caltech was not like it is today. It was a beautiful campus, but I soon felt the total shock of being the first Black woman to set foot on campus as a student. It was a disorienting experience," she says. "The day I arrived on campus was the first time I'd ever seen Caltech."

Carroll came to Caltech from the West Adams neighborhood of Los Angeles, which was a thriving middle-class Black community in the 1970s. Her mother owned the Elegant Manor, a landmark home where neighbors young and old would gather for social occasions. It was Carroll's high school physics teacher, John Essick (MS '43), who persuaded her and two other classmates—James Hong (BS '76) and Elijah Pugh (who later transferred to Cal State Los Angeles and earned a PhD from Howard University)—to apply. It did not take much work on Essick's part. "He said, 'Lauretta, there are two things in life that you want to do: learn to ski and go to Caltech,'" Carroll remembers. "I did not like skiing that much, but he was right about Caltech."

Major Choices

Carroll quickly realized that her high school had not equipped her with all the academic skills needed to succeed at Caltech. "I got there with an incredible deficit," she says, "and there was a huge vertical learning curve. But I managed to get through."

She recalls being in no rush to pick a major and says she swung like a pendulum between subjects such as geology and English. "I was having way too much fun," she says. Her mother finally put an end to her laissez-faire attitude with a surprise 7 a.m. visit in her third year to tell her it was time to start thinking about a job.

"I knew when she was dead serious, and I never messed with her during those moments," Carroll recalls. "That day, I went to the career office and asked if they would show me the starting salaries of all the disciplines. Engineering was at the top."

With her mind made up to become an engineer, she booked an appointment with her advisor to discuss her new major. "I remember talking to my advisor at that time … a middle-aged white guy talking to a young Black woman. I'll never forget what he said: 'You know, Ms. Carroll, you're going to have to pass AMa 95 [Introductory Methods of Applied Mathematics].' That was a make-or-break class for engineers at that time. I just smiled and said, 'OK.' He didn't realize it, but at that moment, he gave me a challenge. Not only was I going to pass it, I was going to do well."

Carroll aced the course, graduated from Caltech, and landed her first job at Hughes Aircraft. "My mama was happy, and I was happy, so it worked out well," she says. She received a scholarship from Hughes to do postgraduate studies at Cornell, where she went on to receive a master's degree in electrical engineering in 1979.

Since 1983, Carroll has run her own software company, Practice Today, which is geared toward health professionals. She has also rekindled an early passion for biology, enrolling in biology classes at a community college. She says the experience has made it clear to her that, as an undergraduate student, she hadn't appreciated the special environment Caltech offered. "I had no idea that magic was happening. At Caltech, I needed to take biology, and there was no textbook; they were using all the papers straight off the press. I was so irritated that there was no textbook that I dropped the class. But lo and behold, the people teaching that class were the same folks I'm reading about now."

Above left: Lauretta Carroll, center, in 2013 with her oldest son, Joseph Van Valen, left, and youngest son, David Van Valen (PhD '11), right, a Caltech assistant professor of biology and biological engineering, and a Heritage Medical Research Institute investigator. **Above right:** Karen Maples, MD, in 2009 after her patient, Nadia Suleman, gave birth to octuplets.

While Carroll worked hard to keep her head above water in her first year, Maples and Hunt had a smoother transition to college life. They took on extra responsibilities, which they both say shaped their future roles in leadership.

Maples held a litany of positions during her student days: she was president of the Caltech Y, the head usher at Beckman Auditorium, a salesperson at the Caltech Ticket Office, scorekeeper for the Caltech track and field team, a lab technician at Huntington Memorial Hospital, and a two-time summer research fellow at JPL.

While Maples had arrived at the Institute with the intention to pursue math, she soon changed her mind. "Everyone starts out in math or physics," she explains. "I went down the rabbit hole of theoretical math classes and realized that math was no longer appealing to me, so in my third year, I switched to biology. There was a professor, Ray Owen [professor of biology, emeritus], who was a great teacher. Leroy Hood [BS '60, PhD '68] was also there. Undergrads had the ability to do research, and I spent a lot of time in the animal lab with rats. I didn't want to deal with rats for the rest of my life, so I opted to apply to medical school."

However, the decision came with tremendous stress, Maples says, because it meant she would embark on a much different career path than she had originally planned—and one that a professor of hers did not understand due to Maples's talents as a researcher. But Owen, Maples's mentor, supported her decision. She went on to attend UCLA Medical School and has worked as an OB-GYN at Kaiser Permanente for 38 years, where she has provided care to thousands of pregnant people, including "the Octomom," Nadya Suleman, who famously had 12 embryos simultaneously implanted in her womb. After eight of the embryos successfully developed, Suleman's prenatal care fell to Maples. "Because I was the chief of the department, she became my patient for the duration of her hospitalization," she says. "There were 52 people involved in this delivery, and I'm not kidding you, we practiced for months."

Hunt entered Caltech as a chemistry major and stayed with the discipline, finishing with an emphasis in biochemistry. She says she found mentors everywhere during her Caltech years. "They ranged from RAs to members of my house, to faculty and grad students," she says. "Mentorship varied from year to year, and I also mentored others, which taught me the importance of mentors."

Hunt became the first woman elected Blacker House president. "That taught me a few lessons in political maneuvering that helped in my corporate life, such as that power and influence are not necessarily held in the top positions," she says.

After starting her career as a bench chemist in the pharmaceutical industry, Hunt moved into regulatory compliance and ran a pharmaceutical consulting business for 22 years before she retired in 2020.

Encountering the "Isms"

In the '70s, Dabney House was the epicenter of Black social life at Caltech, with the largest population of Black students. This motivated Maples to join. "Dabney seemed to be just accepting of all different types of folks, and the social network was really within your house more than anything," she says.

Hunt, meanwhile, was in Blacker, and Carroll was in Lloyd. "Karen, Deanna, and I were alpha females," Carroll says. "We were highly motivated and self-confident. We found our own space at Caltech, while respecting each other's space."

The women had the common experience, however, of encountering the "isms," including racism. "During my undergrad days, I did not have a word for what we now call microaggressions, but the concept was ever present," Carroll says. "There were incidents where I had to show my student ID to prove I belonged, like on the tennis courts or in the library late at night."

However, says Maples, "there was more sexism than racism. I just pushed forward with the notion that I belonged." It was nothing she had not already experienced, she adds. In high school, Maples had tried to get a summer job at an oil company that recruited male interns from her chemistry class. Despite her pushing back and getting an interview, the company still refused to hire her. "That experience stayed with me," she says.

Hunt has similar memories. "I did experience racism, but it paled in comparison to the sexism," she says. "Honestly, the negative experiences were mostly couched in sexism, although racism was likely in the mix as a lot of 'isms' are fellow travelers."

Maples offers some advice to Caltech students who might confront comparable experiences. "Reach out to your mentors, make use of the alumni." As a mentor, she says, "I would encourage you that you can make it."

While each woman had to overcome challenges, some common and others personal, there is no doubt in their minds that they are where they are today because of Caltech.

"I became very successful because the Caltech thinking process trained me in the importance of taking all this data and translating it into patient management," Maples says. "I was able to get into the residency of my choice and go on to Kaiser Permanente."

Hunt agrees, saying that Caltech instilled in her a new way to approach and pursue knowledge. "Caltech taught me that knowledge is readily available; you don't have to carry it around with you," she says. "It is more important to know where to find information and how to use it to answer a question. It is impossible to know everything that you will need."

As for Carroll, she wishes she could go back and be a student again. "You would have to literally drag me off that campus if I had the chance of doing it over," she says. "I could see myself staying there forever." C

Lyndie Chiou, a Caltech Black alumna, graduated with a bachelor's degree in applied physics in 1996. She works as a scientist and science writer, and she is the founder of ZeroDivZero, a website for science conferences. Her writing has also appeared in *Quanta Magazine*, *Scientific American*, and *Sky & Telescope*. Follow her on Twitter @lyndie_chiou.

Above: Deanna Hunt in 2022

Today's Caltech

In the 50 years since Maples, Carroll, and Hunt first arrived at the Institute, Caltech has continued to evolve and, in doing so, has made significant strides to make the campus, programs, and the Institute as a whole more inclusive of all individuals and perspectives. Yet, more work remains. The woman spearheading that effort on campus is Lindsey Malcom-Piqueux (MS '03), who stepped into the role of chief diversity officer and assistant vice president for diversity, equity, inclusion, and assessment (IDEA) in 2021.

As part of her current role at Caltech, Malcom-Piqueux partnered with a group of faculty, staff, postdocs, and students to conduct the first campuswide climate survey, which allowed for a collaborative self-examination across all departments. The survey revealed that while some fields are perceived by Institute scientists to have a more inclusive environment, other disciplines still have work to do. Furthermore, each discipline has its unique challenges and successes.

Once the problems have been identified, Malcom-Piqueux says, the next step is to address them: which is what the Caltech Center for Inclusion and Diversity (CCID), the President's Diversity Council, and many faculty, student, and administrative partners across the divisions and administrative units are now aiming to do. Through these offices and a variety of new and ongoing programs, the Institute is implementing a robust, systemic approach to advance IDEA at Caltech. The work is grounded in a set of shared principles that include a focus on affirmative identity consciousness, an acknowledgment that patterns of inequity exist, and a reliance on data and evidence to guide actions and assess progress, Malcom-Piqueux says. The Institute has also taken intentional steps to make routine processes and functions across Caltech more inclusive, such as hiring, teaching, mentoring, evaluation of staff and faculty, and communications.

"Building a central hub like the CCID to facilitate collaboration and coordination was a big thing," she says, noting that the group, which was previously positioned as a resource primarily for students, has expanded its charge to offer support and space for students, postdocs, faculty, and staff.

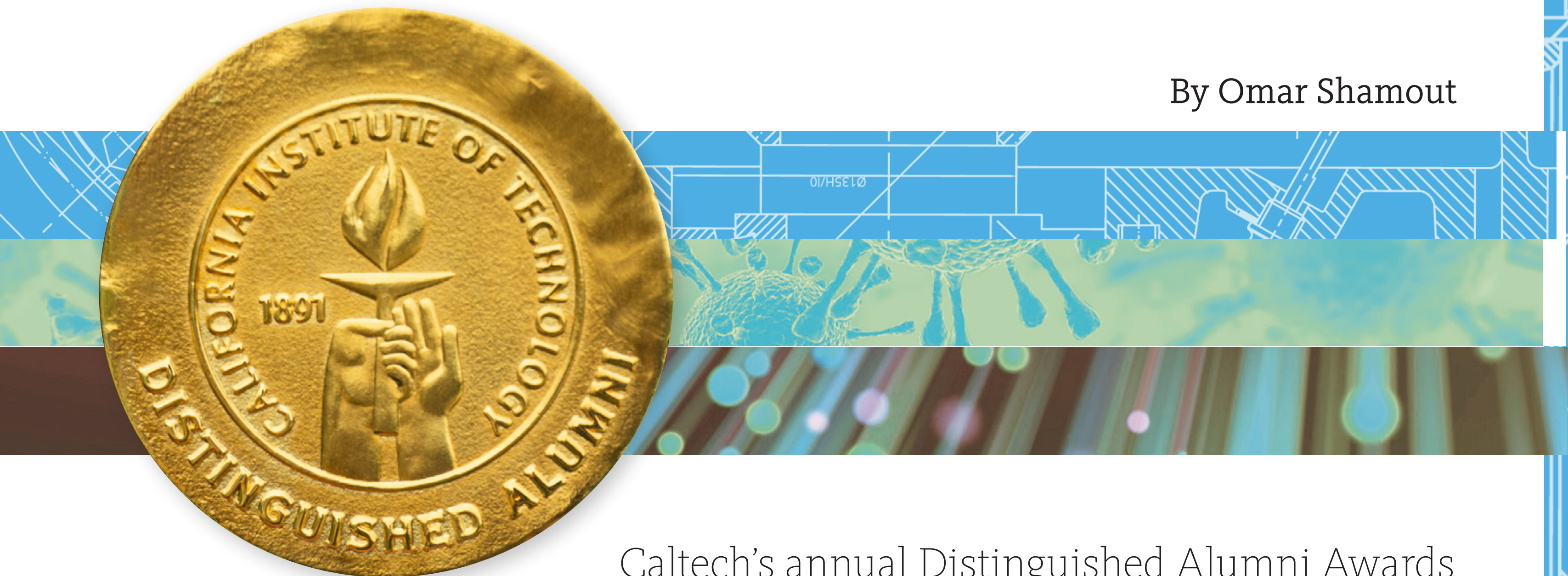
At the same time, CCID is deepening its support structures and programs for students, with the intent of fostering a greater sense of belonging and connection, particularly among individuals who are from historically minoritized communities. In the newly renamed First-Year Success Research Institute (FSRI) program, for instance, CCID helped transition as many as a quarter of this year's first-year students to the Institute this summer in a seven-week intensive orientation program designed to introduce them to Caltech's rigorous research and academic programs and requirements. Formerly known as the Freshman Summer Research Institute, which lasted for seven weeks and was confined to the summer months, the new FSRI now encompasses the whole academic year thanks to a grant from the Gordon and Betty Moore Foundation. The program includes in-depth advising as well as academic success and skill-development workshops; it also encourages more relaxed opportunities to socialize and build community, such as weekly Sunday dinners and even excursions to Disneyland.

Another important new vehicle for progress in inclusion and diversity is the President's Diversity Council, an advisory faculty committee that supports, advises, and provides recommendations for campuswide IDEA efforts. The council implements its own goals and also reviews and advises on new policies proposed by Malcom-Piqueux and leaders from other administrative units. "That group is incredibly engaged with identifying challenges and asking the difficult questions," she says. She also notes that each of the six academic divisions has a DEI committee, and some have hired DEI coordinators.

"We foster an inclusive campus culture and climate by educating and training Caltech community members to implement inclusive approaches and interrupt exclusionary practices," Malcom-Piqueux says.

The 2022 Distinguished Alumni

By Omar Shamout



Caltech's annual Distinguished Alumni Awards recognize "a particular achievement of noteworthy value, a series of such achievements, or a career of noteworthy accomplishment." The 2022 luminaries include India's preeminent earthquake engineer, who helped improve his country's seismic codes; a vaccine designer who first identified the SARS-CoV-2 virus's evolution; and an electrical engineer whose work ushered in the era of broadband cable and wireless internet.

Sudhir Jain

MS '80, PhD '83 , Civil Engineering

Earthquake Engineer and University Administrator

For his lifesaving impact as India's preeminent earthquake engineer; for his research, advocacy, and establishment of training programs for engineers and of seismic building codes; and for his leadership in higher education, first at the Indian Institute of Technology Gandhinagar and then at Banaras Hindu University.

Sudhir Jain arrived at Caltech from India in September 1979 to pursue a PhD in earthquake engineering, and it did not take long for the San Andreas Fault to give him some firsthand experience. On October 15 of that year, a magnitude 6.5 earthquake struck the Imperial Valley and damaged buildings in El Centro, about 20 miles from the U.S.-Mexico border.

"Ron Scott [a former civil engineering professor at Caltech] sent a senior student who was doing a PhD with him to El Centro, and he said, 'Take Sudhir with you,'" recalls Jain. "I went to El Centro, saw what an earthquake can do, and came back with structural drawings of a building that had been severely damaged. Not long after, I was in the library, and George Housner [a former Caltech professor considered to be a pioneer of earthquake engineering] walked up to me and said, 'I hear you have the drawings. Come and discuss it with me.' It was a good early introduction to my studies."

Over the next 35 years, Jain became India's leading earthquake engineer as well as a successful university administrator. As founding director of the Indian Institute of Technology Gandhinagar, where he worked for more than 12 years beginning in 2009, he led the institute to prominence and cultivated an undergraduate engineering program that emphasizes liberal arts education and project-based learning. In early 2022, he started a three-year term as vice chancellor of Banaras Hindu University.

"I moved from a very small new school to Asia's largest residential university, which is more than a hundred years old," Jain says. "It was like you are playing cricket, and now you have to play tennis."

Jain moved back to India after he completed his PhD in 1983, and he began teaching at the Indian Institute of Technology Kanpur. A few years later, a second major quake changed the trajectory of his life. In 1988, Jain visited the site of a 6.6 magnitude earthquake in India's Bihar state, which left more than 1,000 people dead and thousands of others injured in both India and Nepal, and immediately knew he had to do more to help developing nations such as India prepare for this type of natural disaster.

"I went with a couple of students to see what the earthquake had done. When I came back, I realized that saving people from earthquakes is my calling. If there's an earthquake in California, less than 100 people die. But if an earthquake were to take place in India or Pakistan or Iran, maybe 10,000, 20,000 people die, or even more. It didn't make sense. I took a view that publishing in international journals was less important than being useful to the community and society."

He has since worked with government officials to reform India's seismic building codes and implement training programs for engineers. Jain says Caltech helped instill in him the value of working for the public good.

"Caltech taught me to not be very careerist, to not worry too much about promotions or awards or fellowships, things like that," Jain says. "It was a very nurturing experience."

In addition to his real-world reforms, Jain also helped broaden the field of earthquake engineering in his country. Following his advocacy work, which began in the late 1980s, more institutions began to teach earthquake engineering. Before that time, only the Indian Institute of Technology Roorkee, where Jain earned his bachelor's degree in civil engineering in 1979, offered the major.

"I was able to take the field to a lot more institutions," he says. "I was able to build a community of people interested in earthquake engineering, both in academia and outside of academia."

Jain kept up a relationship with Housner, the former Braun Professor of Engineering, Emeritus, until Housner's death in 2008.

"He would from time to time type out a letter and send it to me, sometimes with an article or newspaper clipping, sometimes with a book. He kept me in his thoughts."

Jain describes his time at Caltech as a "life-changing experience," in large part due to the trust the Institute places in its students, which he has tried to implement in his own career.

He has fond memories of other places in Pasadena too. "There was a restaurant, Burger Continental," Jain says. "They used to make some excellent falafel."

Bette Korber

PhD ’88, Chemistry

Theoretical Biologist

For pioneering achievements in virology research and computational vaccine design, providing hope against diseases such as HIV/AIDS, and for continuing to equip the scientific community with insights into HIV and SARS-CoV-2, the virus that causes COVID-19.

A scientist at the Los Alamos National Laboratory in the Theoretical Biology and Biophysics Group, Korber is a global leader in the study of how viruses change over time and how vaccines can be constructed to combat them. Her computational strategies have enabled vaccine designs for highly variable viruses like HIV, hepatitis C, influenza, and filoviruses, and her HIV mosaic vaccine designs are currently being tested in human clinical trials. She has put this vast expertise in tracking variants to use during the COVID-19 pandemic.

“The SARS-CoV-2 virus continues to evolve, and selective forces favor it becoming more infectious and immune resistant. The evolutionary story of this virus is still unfolding,” she says.

One of Korber’s most significant contributions to that story was to initially demonstrate in spring 2020 that SARS-CoV-2 was, in fact, evolving. She analyzed viral sequences sampled globally and found a more transmissible variant of the virus that was rapidly replacing its ancestral form. Whenever it entered a population, the newer form would soon become prevalent locally; this was happening simultaneously in multiple locations around the world. The ensuing paper, published in the journal *Cell* in August 2020, has been cited thousands of times, though it initially drew much skepticism in the biology community.

“In early 2020, most of my peers were saying this virus was not evolving,” Korber says. “I felt strongly the data supported the view that it was becoming more transmissible. Now this is well accepted. Fortunately, I had a great team at Los Alamos, and incredible experimental colleagues led by David Montefiori at Duke, who were able to prove what I was seeing through analyses of the sequence data.”

Mathematical modeling has fascinated Korber since before she arrived at Caltech. “Even then, it was understood that our fossil fuel dependency was eventually going to lead to global warming,” she said. “I was a chemistry major, and I wanted to work on ways you could use solar energy to bypass fossil fuels,” which would have involved mathematical chemistry. But she was assigned to an advisor who had different ideas. “He thought I should do experimental biology because that’s all women could do. He was resolute about this. We argued bitterly about it my first year.”

Korber grudgingly took the biology classes he assigned but found a silver lining: a professor who helped her appreciate the science of immunology. “I had a great teacher, Ellen Rothenberg [Edward B. Lewis Professor of Biology]. Immunology is very beautiful, and she made me want to understand it more,” Korber says. “It turned out to be a good scientific path.”

Around the same time, a Caltech physics student named Brian Warr, a close friend and housemate of Korber and her husband (James Theiler, PhD ’87), became one of the early patients in Los Angeles diagnosed with HIV. His situation played a significant role in her career choice.

“Brian had a magnificent mind and was a wonderful man,” she says. “When he first got HIV, we didn’t fully understand what it meant for him, but we knew that people were dying of this new disease. I hoped that by studying HIV, I could maybe help Brian and ultimately others in his situation. Effective treatment came too late for Brian. We lost him to AIDS in 1992.”

The study of viral evolution and how it impacts vaccine design is transforming, Korber says. The Global Initiative on Sharing Avian Influenza Data (GISAID), which began as a data-sharing hub for influenza sequences, took on SARS-CoV-2 sequences in 2020. GISAID allows researchers to both share and access newly collected viral sequences from all over the world in close to real time. This was a big change from earlier in Korber’s career when the most recent HIV-1 sequences she and others worked with were generally sampled several years, not several weeks, prior. The shortened window enables scientists to define and track newly emergent SARS-CoV-2 variants and resolve phenotypic changes that might impact public health. For COVID-19, it provides vital information regarding when to shift to a new vaccine component, such as the addition of an Omicron variant to the SARS-CoV-2 vaccines this fall.

“There are over 13 million SARS-CoV-2 sequences currently in GISAID,” Korber says. “To mine this unprecedented wealth of data, we are having to invent the computational tools as we use them. Those of us who do the computational work distill this information for our colleagues, who then test the newly emergent variants experimentally as quickly as possible. It’s an ongoing challenge.”

Kam-Yin Lau

BS ’78, MS ’78, PhD ’81, Electrical Engineering

Electrical Engineer

For his innovations in and commercialization of laser diode and radio-over-fiber technologies that broadly enable today’s wireline and wireless high-speed internet access as well as enabling progress in interplanetary exploration, radio astronomy, and particle physics research; and for his remarkable artistic contributions to the Chinese ink painting movement.

The residents of what is now Venerable House had a nickname for Kam-Yin Lau.

“I was known as the invisible man, because they never saw me there,” Lau said. It took a lot of work to complete both a bachelor’s and master’s degree in only three years, and a doctorate three years later. So, Lau preferred to spend time in the lab or to study in what is now called the Caltech Hall library, especially at night, when the dorm became too noisy for him.

“I used to stay very late,” Lau said. “Usually until after the campus security guards made their last round.”

Lau grew up in Hong Kong, where his passion in high school was not science but modern Chinese ink painting. In fact, the Hong Kong Museum of Art acquired one of his pieces when Lau was 16, and it remains in its permanent collection. Five other pieces of his artwork are now in the collection of the Hong Kong Museum of Education.

Lau first heard about Caltech after reading a book about Qian Xuesen (PhD ’39), a student of aeronautics pioneer Theodore von Kármán and one of the founders of the Jet Propulsion Laboratory (JPL), which Caltech now manages for NASA. Though Lau intended to follow Qian’s footsteps in aeronautical engineering, some fellow Caltech students from Hong Kong convinced him that it would not offer a viable career path: he could not work in the United States because he was not an American citizen, and the industry was nonexistent back home. Lau switched to electrical engineering, intrigued by lasers and the burgeoning field of fiber optics. He studied with John R. Pierce (MS ’34, PhD ’36) as an undergraduate and completed his PhD in the lab of Amnon Yariv, the Martin and Eileen Summerfield Professor of Applied Physics and Electrical Engineering.

In the summer of 1979, Lau was invited to participate in a program at JPL that involved the development of an ultrastable radio-over-fiber time-and-frequency synchronization system for arraying widely spaced large antennas in JPL’s Deep Space Network (DSN). If successful, this system would significantly improve tracking and navigation accuracy of interplanetary spacecraft and data rates sent back to JPL. With Yariv’s permission, Lau “moonlighted” at JPL while pursuing his PhD research. By the time he completed his thesis two years later (on high-speed laser diodes), he had finalized the system design with JPL’s George Lutes.

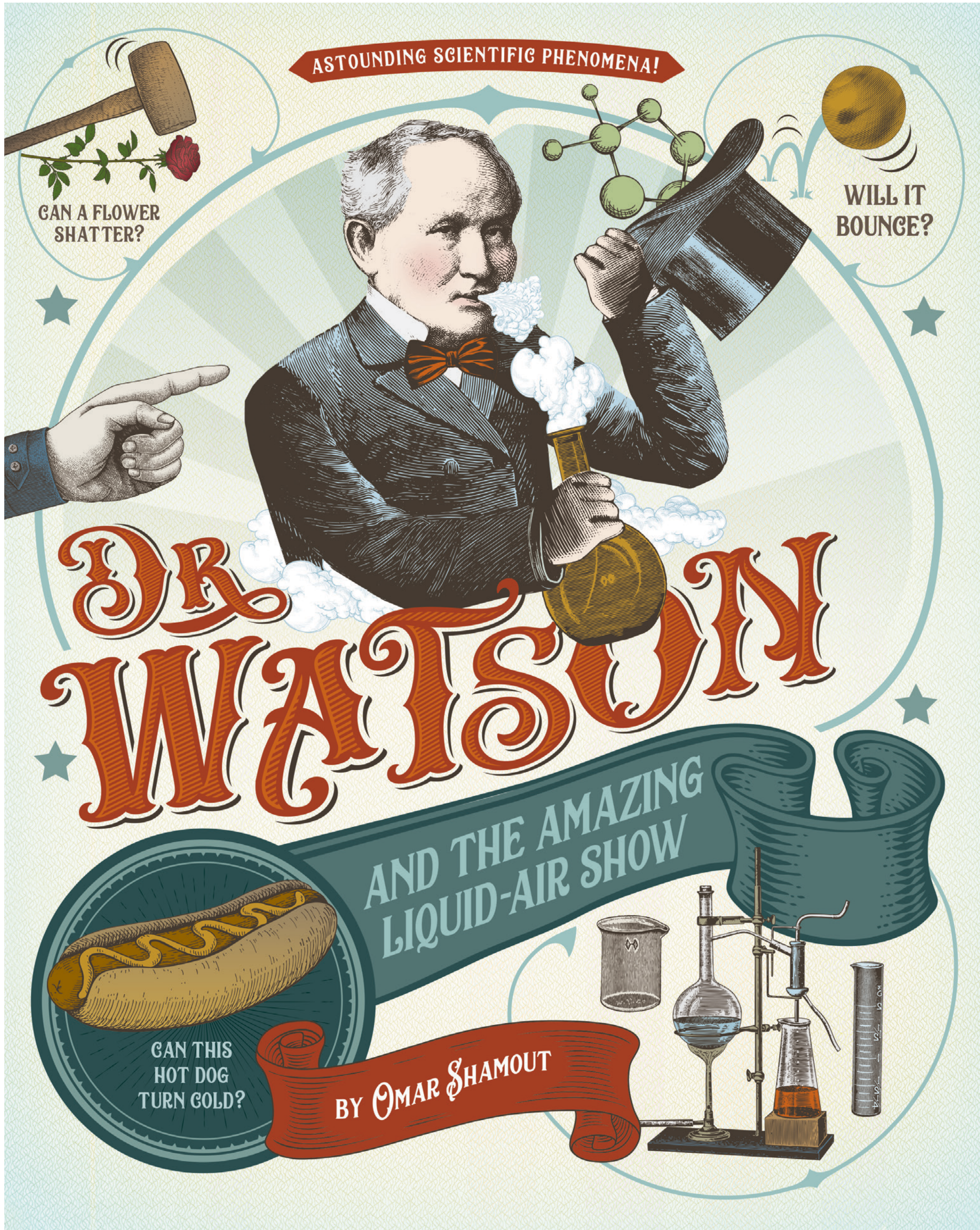
Yariv then invited Lau to join Ortel Corp., a startup he had just co-founded, as its first employee. Lau worked as Ortel’s founding chief scientist until 1988. The company developed and manufactured the high-speed laser diodes and radio-over-fiber links required for implementing the ultrastable fiber system in JPL’s DSN.

This system was put to the test in 1991 when the Galileo spacecraft’s main antenna failed to deploy on its mission to Jupiter, a planet more than 600 million kilometers away from Earth. The antenna arraying capabilities of the DSN antennas that Lau and Lutes’ work enabled, along with data compression and receiver improvements, allowed more than 70 percent of the original mission’s objectives to be completed with Galileo’s smaller, low-gain antenna.

Ortel’s products also provided the infrastructure for cable and wireless internet transmission across the globe. “The radio-over-fiber systems we developed at Ortel transformed the cable industry,” Lau said. “At home, I use bundled TV, internet, and phone services. I think about it once in a while, that this is something my Ortel colleagues and I contributed to.”

After leaving Ortel in 1988, Lau had a two-year stint at Columbia University before he joined UC Berkeley in 1990 as a professor of electrical engineering and computer sciences. Later, he also served as founding chairman of LGC Wireless, a company he started with three of his Berkeley students. LGC’s Distributed Antenna Systems brought broadband wireless coverage to formerly hard-to-reach spaces inside buildings, tunnels, and underground structures.

While Lau’s work has helped enable our fast-paced modern world, he still savors the peace and quiet of the Caltech Hall library. “If I could, I would go back to its top floor at night and take in the view,” Lau said. “Along the crest of Mount Wilson, you could see a line of faint blue lights set against the grid of yellow streetlights below. It’s really quite mesmerizing.” [C]



How Earnest C. Watson wowed crowds with his liquid-air extravaganza and turned a demonstration series into an iconic Caltech showpiece that has lasted 100 years.

The year is 1922, and Caltech physicist Earnest C. Watson stands in front of a packed lecture hall filled with wide-eyed onlookers from across Southern California as he pours what appears to be boiling hot water from a bottle onto a table. Clouds of white fumes engulf Watson, and though it seems as if he should be severely burned, he remains miraculously unharmed.

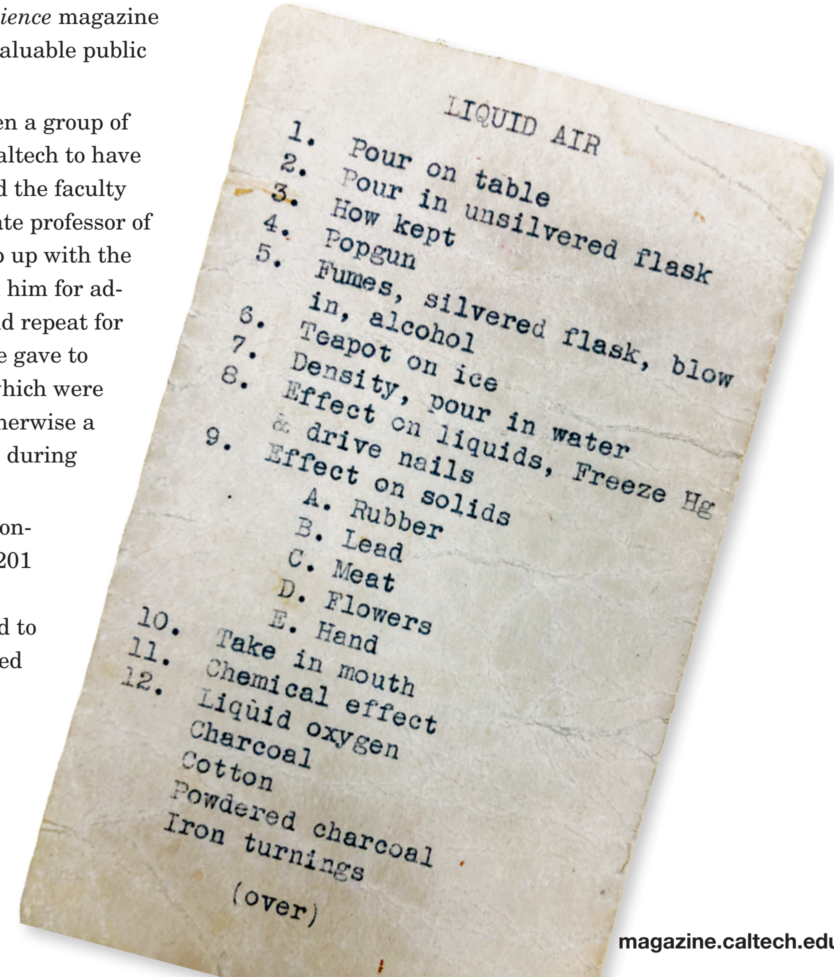
Of course, the result is anything but miraculous, as Watson would go on to explain. It is simply science. The liquid is not water, but air (a mixture of mainly nitrogen and oxygen), and it is cold—very cold—chilled at a temperature more than 300 degrees Fahrenheit below freezing. When the water touches the warmer air outside the bottle, it boils.

"There is really nothing more remarkable about this than there is about water boiling on a hot stove," he would go on to tell the audience, according to his typewritten script.

Such began Watson's famed liquid-air demonstration, which helped popularize an annual suite of demonstrations, and later lectures, that Caltech's *Engineering and Science* magazine in 1959 called "one of the Institute's most valuable public relations efforts."

The series originated a century ago, when a group of local high school science teachers visited Caltech to have a conversation with Watson, who had joined the faculty three years earlier and was then an associate professor of physics. The teachers had struggled to keep up with the latest advances in the field, and they asked him for advice. Watson came up with an idea: he would repeat for them the weekly physics demonstrations he gave to Caltech's first- and second-year students, which were designed to "add a little life to what was otherwise a dry problem course," as Watson told crowds during his liquid-air introductory remarks.

Known first as the Friday Evening Demonstration Lectures, the events took place in 201 East Bridge, now known as the Feynman Lecture Hall. In 1964, the lectures relocated to Beckman Auditorium, and the name changed to the Caltech Lecture Series. In 1972, two


LIQUID AIR
1. Pour on table
2. Pour in unsilvered flask
3. How kept
4. Popgun
5. Fumes, silvered flask, blow in, alcohol
6. Teapot on ice
7. Density, pour in water
8. Effect on liquids, Freeze Hg & drive nails
9. Effect on solids
A. Rubber
B. Lead
C. Meat
D. Flowers
E. Hand
10. Take in mouth
11. Chemical effect
12. Liquid oxygen
Charcoal
Cotton
Powdered charcoal
Iron turnings
(over)

Right: Earnest C. Watson's typed notes for his liquid-air demonstration.

years after his death, the Institute recognized Watson by renaming the series in his honor.

The Earnest C. Watson Lecture Series, which was popular from its inception, has always been free and open to all. "Realizing the general public's interest in the Institute and in the results of science, the Institute has decided to invite the general public to attend these lectures. Modern points of view will be emphasized and some of the great epoch-making experiments will be reproduced," read the original press release from October 12, 1922. So many people showed up in the early days (Watson noted that one couple drove in regularly from Hemet, in the San Jacinto Valley) that lectures often had to be repeated in the same evening to accommodate the crowds.

Judith R. Goodstein, former university archivist at Caltech, along with her husband, David L. Goodstein, the Frank J. Gilloon Distinguished Teaching and Service Professor, Emeritus, and professor of physics and applied physics, emeritus, presented a 1997 Watson Lecture called "Earnest Watson and the Amazing Liquid-Air Show," during which David Goodstein recreated some of Watson's demonstrations.

Though Watson presented on other topics, including "The Science of Musical Sounds," it was the liquid-air demonstration that became his calling card. Judith Goodstein said Watson was inspired by similar Friday evening lectures at the Royal Institution in London, specifically a talk given by James Dewar in 1904, in which the Scottish chemist demonstrated how to liquefy hydrogen gas, a feat he had become the first to accomplish six years earlier.

Watson, in order to elicit further reactions from the audience, would swirl liquid air in his mouth, freeze liquid mercury into a solid hammer and use it to drive nails, and dip flower bouquets, hot dogs, and rubber balls into liquid air and promptly shatter them, among other crowd-pleasing demonstrations.

Early speakers in the series also included Charles Galton Darwin (a visiting professor and grandson of Charles Darwin), whose topic was gyrostats; Arnold Sommerfeld, a distinguished physicist from the University of Munich, who offered a lecture demonstration on oscillations and resonance phenomena; and Caltech's Arnold Beckman, then an assistant professor of chemistry, who frequently presented on the subjects of ionic theory and atmospheric gases.

Over time, the Watson Lectures ventured into fields of scientific research beyond physics. Linus Pauling, the late Nobel laureate and Caltech professor of chemistry, spoke on the nature of chemical bonds. Harry Bateman, the late Caltech professor of mathematics, physics, and aeronautics, gave a presentation about the humorous side of mathematics.

In recent years, the Watson Lecture Series has featured such Caltech luminaries as Kip S. Thorne (BS '62), Richard P. Feynman Professor of Theoretical Physics, Emeritus, who spoke about black holes, wormholes, time travel, and gravitational waves; Ken Farley, W. M. Keck Foundation Professor of Geochemistry and Mars 2020 project scientist, who discussed the Perseverance mission; and Dianne Newman, Gordon M. Binder/Amgen Professor of Biology and Geobiology, who explained how her lab is trying to better understand the microbes that thrive without oxygen and cause chronic infections.

"The Watson Lectures are a key part of Caltech's intellectual life; they are both a place where the Institute's research meets the surrounding community, and an opportunity for us to pause and reflect on the broader meaning and impact of our work," says John Eiler, the Robert P. Sharp Professor of Geology and Geochemistry, and chair of the Institute Programs Committee, which plans the Watson Lecture Series.

Back in his day, Watson himself, along with his liquid-air show, were star attractions that helped Caltech forge a strong bond with the community. In fact, the demonstrations became so popular during his tenure at Caltech that Watson grew to be in great demand up and down the West Coast as a speaker. His show remained a hit even after his retirement in 1959 as a professor of physics and dean of the Caltech faculty. The Institute asked Watson to revive the show to mark the series' move to the newly built Beckman Auditorium on October 12, 1964. A Caltech press release at the time described the presentation as "a one-man scientific circus performance."

"I remember seeing Earnest loading his car prior to one of his often long and strenuous trips with his famous liquid-oxygen demonstration," wrote the late Ernest Swift, former Caltech professor of analytical chemistry and chair of the Division of Chemistry and Chemical Engineering, in Watson's 1970 obituary. "I think those trips were one of the most effective means ever used for establishing good relations with the high schools of the west."

Claire Bucholz, assistant professor of geology, will present the next lecture in the 2022-23 season on January 18, 2023, with "When Earth Breathed Deeply," in which she will discuss how our planet's atmospheric oxygen levels have increased by many orders of magnitude over time, profoundly affecting biological and chemical cycles on Earth's surface.

A playlist of recent Watson Lectures available to watch on YouTube can be found here:

Right: Watson giving his liquid-air demonstration in Beckman Auditorium on October 12, 1964.

Demonstrations of this kind should be undertaken only after thorough training and with the use of proper safety equipment.

Life on Mars?

Samples taken by the Perseverance rover show the presence of organic material.

By Robert Perkins

As NASA's Mars Perseverance rover explores Jezero Crater on the Red Planet, scientists at Caltech will help humanity discover whether the samples it collects hold signs of ancient extraterrestrial life.

The rover is currently traversing the remnant of a delta where, about 3.7 billion years ago (when liquid water still flowed on the Martian surface), an ancient river terminated in a lake. On September 15, 2022, the Perseverance team announced that the rover had detected organic compounds in a location called Wildcat Ridge. While the compounds can be produced abiotically, some could be biosignatures.

"In the distant past, the sand, mud, and salts that now make up the Wildcat Ridge sample were deposited under conditions where life could potentially have thrived," said Ken Farley, the W. M. Keck Foundation Professor of Geochemistry and Perseverance project scientist. "The fact the organic matter was found in such a sedimentary rock—known for preserving fossils of ancient life here on Earth—is important. However, further conclusions will have to wait until it's returned to Earth for in-depth study as part of the agency's Mars Sample Return campaign."

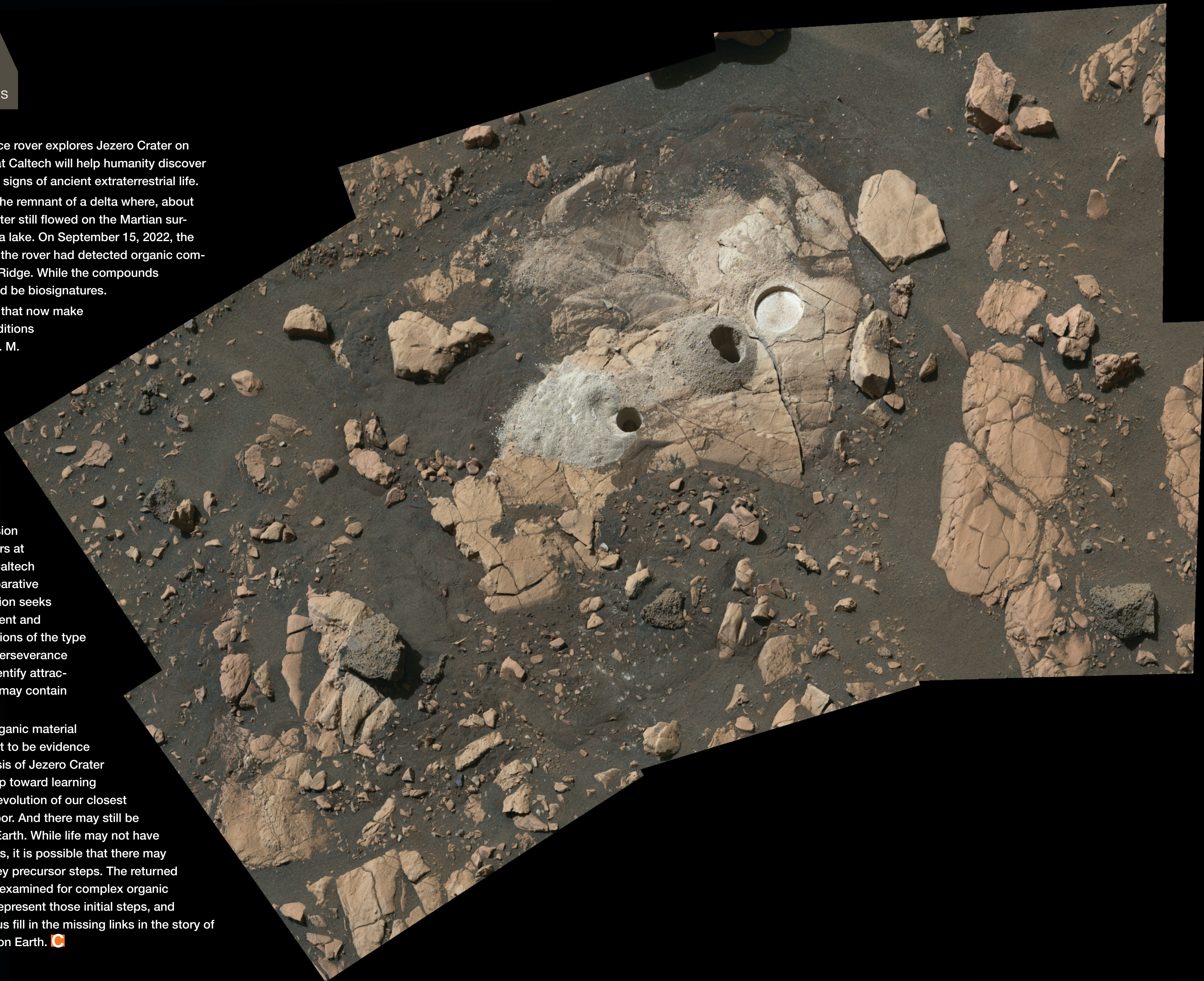
The rover had previously made the notable yet surprising discovery of igneous rocks in the base of Jezero Crater. Igneous rocks, such as the basalt that makes up island chains like Hawai'i, are cooled flows of magma that have solidified underground or emerged during volcanic eruptions. Sedimentary rocks, on the other hand, are the result of rocks that eroded into fine grains and cemented together into a single rock through heat, pressure, and chemical processes.

"The finding of igneous rocks in the floor of the crater says that Jezero is more complex than the model of a lake basin that is filling with sediments over time with the delta being the last landform," says Bethany Ehlmann, professor of planetary science and associate director of the Keck Institute for Space Studies. "It says that the region has had a rich geological history that has had both igneous and sedimentary processes."

The fortuitous (and forward-thinking) large concentration of geochemists at Caltech preparing to analyze Martian samples mirrors a similar situation two generations earlier, when Caltech was home to some of the first geologists, geophysicists, and geochemists to analyze lunar samples brought home by the Apollo astronauts.

"Planetary geology was essentially invented at Caltech," says John Grotzinger, the Harold Brown Professor of Geology and Ted and Ginger Jenkins Leadership Chair of the Division of Geological and Planetary Sciences. "The close proximity to JPL, and Caltech's small size, allowed close collaborations between scientists in the GPS division and the PMA [Physics, Mathematics and Astronomy] division with the engineers at JPL." The new Caltech Center for Comparative Planetary Evolution seeks to stimulate current and future collaborations of the type needed by the Perseverance rover team to identify attractive targets that may contain biosignatures.

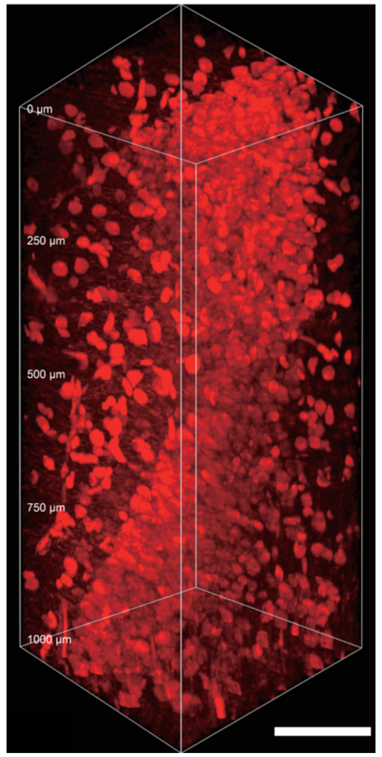
Even if the organic material does not turn out to be evidence of life, the analysis of Jezero Crater will be a firm step toward learning more about the evolution of our closest planetary neighbor. And there may still be connections to Earth. While life may not have emerged on Mars, it is possible that there may be a record of key precursor steps. The returned samples can be examined for complex organic molecules that represent those initial steps, and these may help us fill in the missing links in the story of how life started on Earth.



Points *of View*

With a wave of new and improved technologies, Caltech researchers continue to change the way we visualize the worlds both in and around us.

By Katie Neith



Super-resolution and volumetric tissue imaging by specialized microscopy can map chemical vibrations from proteins in the brain.

Chemist Lu Wei can remember the first time she truly saw the results of her research. The moment came when she was a graduate student and, with her lab mates, built a microscope. "When we got our first image, I literally jumped around," Wei says. "Seeing really is believing."

Wei has leaned into that sense of excitement ever since. Now in her own lab at Caltech, she uses new spectroscopy and microscopy methods to delve deep into biological tissues and track individual molecules in living cells.

Wei is just one of many scientists and engineers at the Institute hard at work producing better pictures of objects as small as individual cells, as deadly as breast cancer tumors, and as far away as black holes. In an attempt to see deeper, farther, and faster, these researchers push the boundaries of traditional techniques by using new approaches, including some that incorporate artificial intelligence (AI), to identify patterns beyond the scope of the human eye.

Good Vibrations

To truly understand diseases and develop better ways to treat them, one needs to know what is happening in the body on a cellular level. Wei aims to do that through the design of innovative imaging techniques that exploit the unique vibrations of chemical bonds—which stretch and bend due to the constant motion of atoms—to visualize small biomolecules with high precision and resolution using the detected vibrations as coordinates. "For example, water molecules are made of O and H bonds that vibrate at a particular frequency," Wei explains. "We can detect that vibration and map out where the water is in our cells and tissues and bodies."

Wei's team has built on this knowledge about how different chemical bonds vibrate and has developed nontoxic chemical tags that give off particular vibrations. These tags can be introduced into molecules to help researchers track them in the complex environments of living cells.

Thanks to a specialized type of microscopy developed by Wei that can pick up the subtle vibrations, she has been able to probe the metabolic processes—or life-sustaining chemical reactions—inside different types of cells.

"With cancer and other diseases, we're trying to find new or additional targets associated with metabolism that could help improve the efficiency of treatments," Wei says. "Previously, we used this approach to pinpoint a couple of metabolic susceptibilities in melanoma cancer cells at the stem cell level. What was very impressive was that we were able to identify a process that directly linked to a very aggressive type of cancer cell."

Now, she uses the same technologies and processes to explore metabolic regulation in cardiovascular disease and in brain tissue. "Because we're in chemistry, we like to understand the fundamental aspects of exactly how something is being controlled," Wei says.

That kind of deep dive into how systems are regulated could also be used in efforts to make lithium-ion batteries safer. Following up on a project Wei initiated in 2018, the team plans to track the chemical dynamics of electrolyte distributions in batteries during charge cycles to figure out how to keep the batteries cooler. This could help address current safety issues that include fires, which are often caused by conditions related to electrolyte imbalances.

"In addition to biology, which is still my main interest, the instruments and techniques we're developing have potential applications for other fields like renewable energy and materials science that I plan to explore further," she says.

Seeing with Sound

Chemical engineer Mikhail Shapiro also wants to track functions cell by cell in the body to develop better health diagnostics and therapies: no easy feat, given that the human body holds some 37 trillion cells. But he uses a different kind of vibration—sound waves, rather than vibrations caused by motion—to image activities deep within a cell's natural habitat.

To do this, Shapiro has pioneered a technique that uses genetic engineering to make genes dubbed "acoustic reporters" that produce air-filled proteins called gas vesicles when inserted into a cell. These vesicles, or "acoustic proteins," contain pockets of air that can reflect sound waves, which allows them to be located and tracked using one of the most widely used imaging techniques in the world: ultrasound.

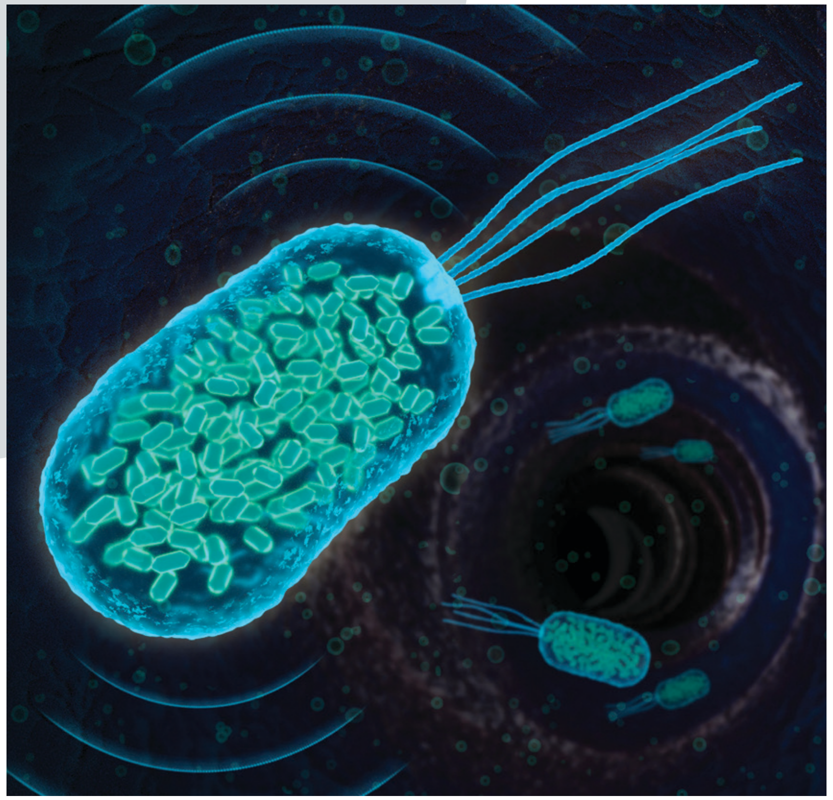
"The challenge has been that, historically, ultrasound has showed us anatomy, like where bones and muscles are, but it couldn't show us specific cells," Shapiro says. "Now, not only can we see where cells are located, but we can also look at their function because we can program them to only make the gas vesicles under certain conditions. This has opened up new potential for deep-tissue cellular imaging that was not previously possible."

Shapiro and his team can also amp up the ultrasound waves to a strength that can pop the gas vesicles instead of just pinging them; this results in a stronger signal that allows researchers to see much smaller quantities of the vesicles. This increased sensitivity has the potential to improve studies of the gut microbiome, where a large portion of immune cells live, by being able to home in on just a few cells in a sea of many. "One of our near-term ambitions is to visualize immune cells as they go around the body and seek out and attack pathogens or tumors," Shapiro says. "We want to watch this drama unfolding in real time."

As someone who studied neuroscience as an undergraduate, Shapiro is also heavily invested in learning about the brain. In fact, a lack of effective noninvasive technologies with which to study neurons is what drove Shapiro to pursue a PhD in biological engineering.

Last year, he received grants for two neuroscience studies from the National Institutes of Health's Brain Research Through Advancing Innovative Neurotechnologies (BRAIN) Initiative. One of these BRAIN-funded projects aims to image neural activity using ultrasound on a brain-wide scale as a means to help understand and develop better treatments for neurological disease. The other study is focused on brain-computer interfaces, and it involves the use of ultrasound to record brain signals in a less invasive way than current implants. The information gained from this study could, for example, be used to help paralyzed patients learn to perform various tasks with neuroprosthetics.

Ultimately, Shapiro hopes the technologies he develops will become a model for various types of research, with biology labs across the world placing ultrasound machines next to their optical microscopes. "In addition, I will be happy if physicians start using ultrasound to look at where their cell and gene therapies go inside the body and what they're doing, so they can take corrective actions if the therapy is not doing what they want," he says. "I hope that our acoustic proteins will make it possible for many more laboratories to see previously invisible things inside living beings."



An artist's representation shows gas vesicles inside a bacterium.

Laser Focus

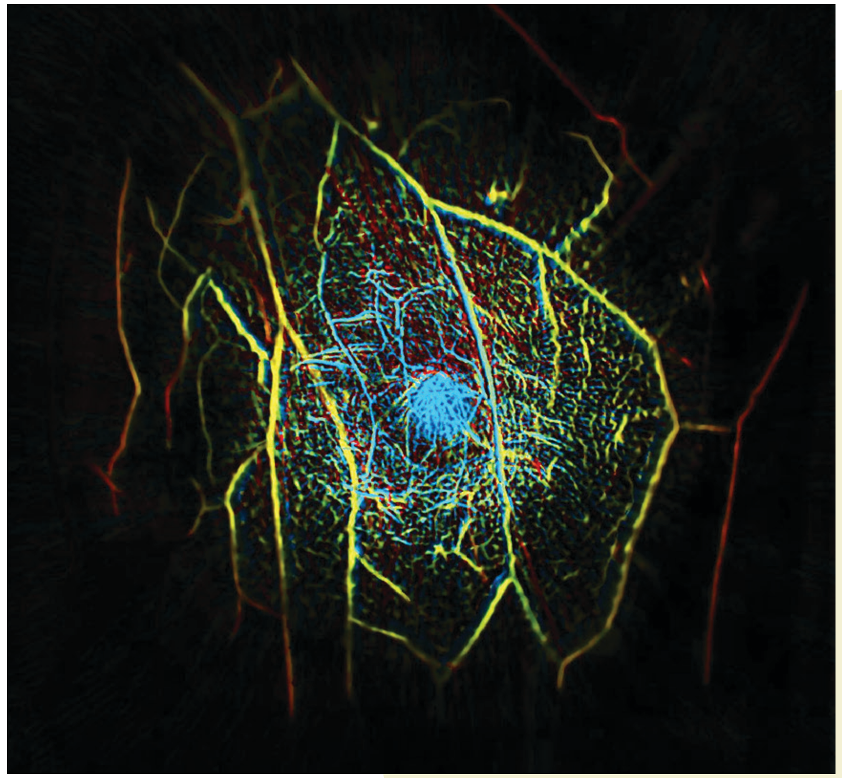
In 2014, Caltech engineer Lihong Wang announced that he had succeeded in his quest to build the world's fastest camera, the first one capable of capturing a light pulse, or laser beam, as it moves. Since then, he has improved upon his technology and built cameras that can see light scatter in slow motion, observe seemingly transparent objects, and produce 3-D videos. "We have to understand light before we fully understand the world and fully understand nature," Wang says. "Light has the ultimate speed limit if Einstein is still correct. With our camera, for the first time, we can actually see a light pulse at light speed."

Last year, in the January 13 issue of *Science Advances*, Wang reported on progress in his team's study of chaotic systems with his compressed ultrafast photography (CUP) camera, capable of speeds as fast as 70 trillion frames per second. Chaotic systems, such as air turbulence and certain weather conditions, are notable for exhibiting behavior that is predictable at first but grows increasingly random with time. Their experiment observed laser light—which moves at extremely high speeds—scatter in a chamber designed to induce chaotic reflections. Figuring out how light moves under chaotic conditions has applications in physics, communications, cryptography, and flight navigation.

In addition, with a few modifications, Wang has used his ultrafast camera to capture signals traveling through nerve cells for the first time, a feat reported in the September 6 issue of *Nature Communications*.

Like Shapiro, Wang also creates medical imaging techniques that utilize ultrasound but work in combination with lasers. He has invented a number of photoacoustic imaging techniques that combine light and sound waves for deep, noninvasive views of biological tissue without the risk of radiation. For example, his laser-sonic scanner for detecting breast cancer tumors is currently being developed for use in health care facilities. It can pinpoint tumors in 15 seconds without the discomfort or radiation of mammograms, the current gold standard in breast cancer screening.

"We use a safe dose of laser light with the right color that can actually penetrate quite deeply into biological tissue, but the light won't go straight, like X-ray does; it will just wander around," Wang explains. "That's why we resort to photoacoustics. When molecules like blood hemoglobins absorb light, they will start to vibrate, and that vibration is a sound source. We capture that sound signal, and then we can pinpoint where that signal is from and form an image."



An in vivo photoacoustic tomography image, captured by Lihong Wang's lab, of a human breast.

He compares the process to how lightning and thunder work: the lightning is the laser pulse and the thunder is the sound you expect to hear some seconds later. In the same way that you can triangulate the location of a storm using the time between these weather phenomena, Wang and his collaborators can construct an image inside the body.

"You can argue that we're extending what our eye can see far beyond the skin," says Wang, who recently used his photoacoustic imaging techniques to look inside the brain and detect minute changes in blood concentration and oxygenation. "We're showing surgeons what they would see after cutting open a body without having to do so."

New Angles

While Wang works to see *through* objects, Changhuei Yang tries to also see *around* them. In May 2022, he and members of his lab reported in *Nature Photonics* on a technique that can detect an object of interest outside a viewer's line of sight. The imaging method operates by using wavefront shaping, in which light is banked off a wall to generate a focused point of light to scan the object, allowing researchers to see what is out of sight.

"This technology might have use in the future for self-driving cars, as well as for spacecraft traversing around a planet where there might be, say, hidden caverns that they want to explore," Yang says. "Something like this would allow us to do non-line-of-sight imaging and interrogation of an environment in a unique way."

But peering around corners isn't the only way to find hidden objects and patterns. The bulk of Yang's work involves the development of better microscopes, through the use of sensors and computational methods, to see more deeply into biological tissues than ever before and extract information from those samples. He has also begun to use deep learning, a type of AI, to detect patterns in biological imaging that a human observer would not be able to spot.

"There are things that are likely predictive of diseases that human eyes simply cannot pick up on because our ability to recognize patterns is limited," Yang says.

In essence, Yang wants to make machines that can be taught to see better than us, and he has made significant progress. In collaboration with Magdalena Zernicka-Goetz, Bren Professor of Biology and Biological Engineering, Yang has developed a way to use machine learning algorithms to detect subtle pattern differences in images of embryos during the in vitro fertilization (IVF) process that could indicate whether they are healthy and will result in a successful pregnancy or not.

Together with pathologists from Washington University in St. Louis, Yang and his team recently sought to verify a hypothesis many oncologists believed to be true: that if cancer cells are well encapsulated by connective tissues, they will not spread to other parts of the body. Instead, a machine learning analysis of tumor sample images for which the outcome was known indicated the opposite: when the encapsulation is leaky, metastasis risk appears to be lower. A possible explanation for why this may be true is that white blood cells are able to enter and keep the cancer cells in check.

"This whole area of building instruments and algorithms is very rich in terms of the opportunities for actually coming up with new innovations," says Yang, who recently launched a new project aimed at making a camera to image root-soil interactions underground to learn more about the effects of climate change on crops and vegetation. "And being able to make an impact in a meaningful way is really fulfilling. Knowing that, one day, what we're doing is going to maybe have a profound impact on pathology, for example, or IVF procedures, is something that I think drives not just me but the rest of my group as well."

Cameras That Compute

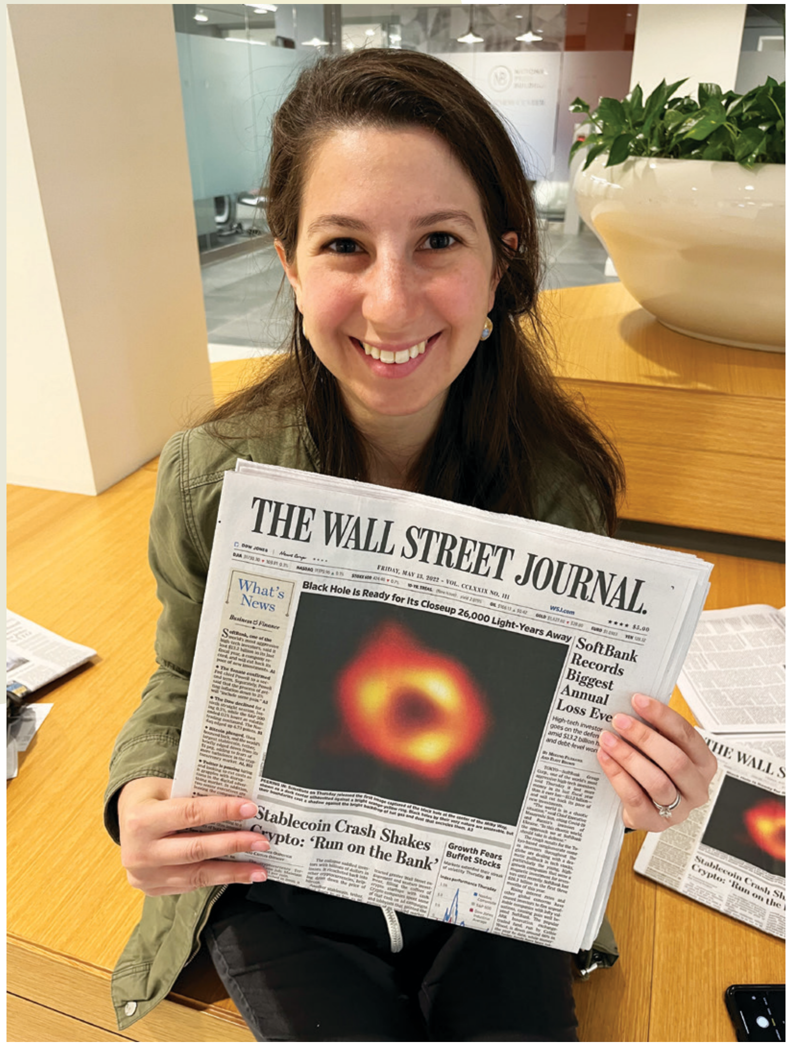
Computer scientist Katie Bouman also uses AI to help compile images that would otherwise be impossible to create. But while Yang and his colleagues focus, both literally and figuratively, on microscopic cells and molecules, Bouman typically sets her sights on much bigger objects, like black holes, and she builds instruments that reimagine the role and function of cameras themselves in order to do it.

"For hundreds of years, cameras have been modeled off of how our eyes work, but that can only get you so far," Bouman says. "We're exploring what happens if you allow yourself to break the standard model for what a camera should look like. By solving for novel computational cameras that merge new kinds of hardware with software, the hope is that the synergy between them will allow you to recover images or see phenomena that are not possible to see using traditional approaches."

Bouman first became interested in computational cameras as a graduate student at MIT, where she worked on the Event Horizon Telescope (EHT) project as a member of the team that produced the first image of a black hole in 2019. Since joining Caltech that same year, she has continued this work and led a Caltech-based team of key contributors to the EHT Collaboration's most recent achievement: generating the first image of the supermassive black hole at the center of the Milky Way galaxy. "The big challenge of imaging any black hole is that they're so far away and so compact that they're really, really small in the sky," Bouman says. "I like to say that the size is equivalent to the size of a grain of sand, if that grain of sand is in New York and I'm viewing it from Los Angeles."

To take an actual picture of something so minuscule, she says, would require a telescope the size of Earth. Instead, the team took images from telescopes around the world to form one single image with the help of algorithms to piece together the blank spots. "If we only collect light at very few points around the world, we have to fill in the missing information," Bouman explains. "And we must fill it in intelligently. My main goal was to take the data that we collect and to recover the underlying picture. It's not like a normal camera where you collect all the information and you can see it with your eyes. You have to make sure that you've captured the range of possible images that could explain the data."

A simple version of this kind of complex computational camera exists in smartphones. When you take a photograph using the high dynamic range (HDR) function, it actually produces numerous photos taken at different shutter speeds. The camera then employs an algorithm to pull out pieces of data from each of those images to create a composite of all the best parts. Similarly, the cameras that Bouman and her research group design are combining sensors and AI to achieve images, on many different scales, of objects and phenomena never seen before.



Katie Bouman and her group made front-page news in May 2022 for generating the first image of the Milky Way galaxy's supermassive black hole.

Like most imaging technologies, computational cameras have medical applications too. With machine learning expert Yisong Yue, professor of computing and mathematical sciences and co-director of Caltech's AI4Science initiative, Bouman has worked to both speed up and improve MRI machines through the development of algorithms that help the machine adjust the images it takes in real time. (Currently, MRIs must rely on predetermined sample locations.) "Our approach allows for decisions to be made as the patient is being scanned to try to get the most informative measurements in the shortest amount of time," Bouman says.

While she expects to continue her pursuit to improve astronomical imaging, Bouman says she is interested in applying her computational cameras to fields beyond those she has already explored, such as seismology and robotics. "The small size of Caltech allows me to collaborate so much more easily across disciplines," she says. "There are so many potential applications around campus; the challenge now is how to choose among them, because you can't do everything." [C]

Katie Bouman is an assistant professor of computing and mathematical sciences and electrical engineering and astronomy, a Rosenberg Scholar, and a Heritage Medical Research Institute Investigator. She is supported by a National Science Foundation CAREER Award, the NSF Next-Generation Event Horizon Telescope Design grant, an Okawa Foundation Research Grant, a Heritage Medical Research Fellowship Award, a Schmidt Futures award, and Caltech's Sensing2Intelligence (S2I) initiative and Clinard Innovation Fund.

Mikhail G. Shapiro is a professor of chemical engineering, a Howard Hughes Medical Research Institute Investigator, and an affiliated faculty member of the Tianqiao and Chrissy Chen Institute for Neuroscience at Caltech. His research is supported by the National Institutes of Health (NIH), the U.S. Army, the Chan Zuckerberg Initiative, the David and Lucile Packard Foundation, and the Pew Charitable Trusts, as well as Caltech's Jacobs Institute, Donna and Benjamin M. Rosen Bioengineering Center, and Center for Environmental Microbial Interactions.

Lihong Wang is the Bren Professor of Medical Engineering and Electrical Engineering, the Andrew and Peggy Cherng Medical Engineering Leadership Chair, and executive officer for medical engineering. His work is funded by the NIH.

Lu Wei is an assistant professor of chemistry and a Heritage Medical Research Institute Investigator. Her work is funded by the NIH, the Alfred P. Sloan Foundation, and the Shurl and Kay Curci Foundation.

Changhuei Yang is the Thomas G. Myers Professor of Electrical Engineering, Bioengineering, and Medical Engineering and a Heritage Medical Research Institute Investigator. Funding from the NIH, Amgen, and Caltech's Donna and Benjamin M. Rosen Bioengineering Center supports his work.

Truth in Numbers

The Human Impacts Database seeks to catalog our relationship with Earth

By Lori Dajose

When you buy a cheap hamburger, you may not realize how many ways your meal illustrates a grand narrative about how humans have shaped the planet. Consider the land used to raise beef cattle, the water required to raise those cattle, the fuel used to transport the beef all over the world, and the human progress that enables us to easily buy a burger—and, for that matter, hop on a plane, charge our phones, and take part in the multitude of activities that make up our everyday experiences.

Caltech researchers in the laboratory of Rob Phillips, the Fred and Nancy Morris Professor of Biophysics, Biology, and Physics, have developed a statistical repository to quantify how humans have impacted the planet. The Human Impacts Database is designed to be accessible to scientists, policymakers, and everyday citizens. It provides information such as global plastic production (4×10^{11} kilograms per year), the number of cattle on Earth (about 1.6 billion), and global annual mean sea level rise (approximately 3.4 millimeters per year). The data are broken into five main categories: water, energy, flora and fauna, atmospheric and biogeochemical cycles, and land. Where available, the database explains how these numbers have changed through the years.

Former graduate students Griffin Chure (PhD '20) and Rachel Banks (PhD '22) led the project. A paper describing the research appeared in the journal *Patterns* on August 3, 2022. The team hopes that access to simple numbers about human impacts will help people make more informed decisions. "For example, a friend texted me asking how to compare the impact of dairy cattle versus beef cattle," Chure says. "We can use our database to figure out that, in terms of land requirement, greenhouse gas emissions, and water use, beef cattle are more impactful by a factor of five or more on a per-calorie basis."

The project takes a planet-wide approach rather than sorting by country or region. "We also draw data from all sorts of different resources: scientific papers, governmental and intergovernmental reports, and industry reports in some cases," Banks says.

The team plans to update the numbers as new data comes out. The project was funded in part by the Resnick Sustainability Institute at Caltech.

Global human population

7.6 billion

Global glacier mass loss between 2006-2015
$(2.78 \pm 1.13) \times 10^{14}$ kg / yr

≈140 billion pickup trucks

Passenger air transport energy consumption in 2020
$\approx 6.6 \times 10^{18}$ J / yr

≈2 billion light bulbs

Global urban land area in 2015
$(7.47 \pm 0.15) \times 10^{11}$ m²

≈100 million soccer fields

Global agricultural land use in 2018
$\approx 4.85 \times 10^{13}$ m²

≈7 billion soccer fields

Global annual plastic production
$(2.9 \pm 0.4) \times 10^{11}$ kg / yr

≈3 billion refrigerators

Global annual mean sea level rise

≈3.4 mm/yr

CO_2 emissions of light-duty vehicles in the United States in 2020 ≈ 0.21 kg CO_2 / km

≈ 350 grams of CO_2 /mile

Standing population of:

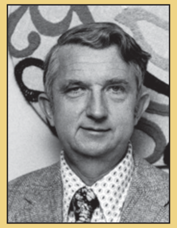
Chickens	Pigs	Cattle
37 billion	**1.4** billion	**1.6** billion

The Human Impacts Database
anthroponumbers.org

In Memoriam

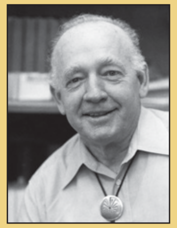
Read more about their lives at **magazine.caltech.edu/post/in-memoriam**

Richard Albert Dean (1924–2022)



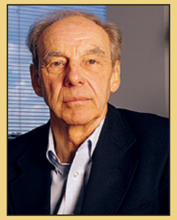
Richard Albert Dean (BS '45), a professor of mathematics at Caltech from 1955 to 1987, passed away on January 27, 2022, at age 97. Dean's achievements in mathematics include showing that the word problem in a finite presented lattice (a certain type of algebraic structure coming from order theory) is solvable. He later applied lattice theory to problems in economics.

Leon T. "Lee" Silver (1925–2022)



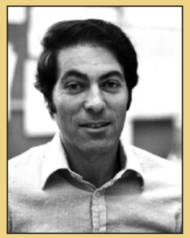
Leon Silver (PhD '55), W. M. Keck Foundation Professor for Resource Geology, Emeritus, at Caltech, passed away on January 31, 2022, at age 96. When Silver joined the Caltech faculty as an assistant professor of geology in 1955, he served as a geologist in the newly formed geochemistry group and studied geological formations in Arizona and the San Gabriel Mountains while also working for the U.S. Geological Survey. Silver later instructed Apollo astronauts on geology and lunar sample selection and developed approaches for using isotope ratios for geochronology.

Juris Hartmanis (1928–2022)



Distinguished Alumnus Juris Hartmanis (PhD '55), founding chair of Cornell University's Department of Computer Science, passed away on July 29, 2022, at age 94. Hartmanis was widely recognized for establishing the field of computational complexity theory. He discovered a set of fundamental laws that govern the difficulty of computation, laying the foundation for a comprehensive theory of the efficiency and limits of computing. At Cornell, Hartmanis built one of the world's first computer science departments.

Thomas G. Phillips (1937–2022)

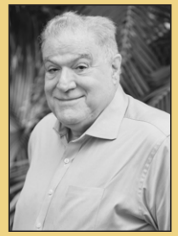


Thomas G. Phillips, the John D. MacArthur Professor of Physics, Emeritus, passed away on August 6, 2022, at age 85. Phillips was a pioneer in observational astronomy. In the 1980s, he led the development of Caltech's Owens Valley Radio Observatory (OVRO) millimeter-wave interferometer as well as the Caltech Submillimeter Observatory (CSO) in Hawaii. In the late 1970s, while at Bell Laboratories, Phillips led the design and optimization of a new type of detector for submillimeter astronomy called the SIS receiver (for superconductor-insulator-superconductor), which enabled the recent black hole images produced by the Event Horizon Telescope Collaboration (see page 30), and much more.

Maarten Schmidt (1929–2022)

Maarten Schmidt, Francis L. Moseley Professor of Astronomy, Emeritus, passed away on September 17, 2022, at age 92. Schmidt is well known for his 1963 discovery of quasars—extremely bright and distant cosmic objects powered by active supermassive black holes. He joined Caltech in 1959. Early in his career, he outlined a relationship between gas density and star formation rate in a given region, which came to be known as the Schmidt law. Since his observation of a quasar in 1963, thousands of these active galactic nuclei have been identified, and they have given astronomers deep insights into the history of our universe.

Philip M. Neches (1952–2022)



Philip M. Neches (BS '73, MS '77, PhD '83), founder of Teradata Corporation, venture partner and lead mentor at Entrepreneurs Roundtable Accelerator, and a Caltech trustee, passed away on September 25, 2022, at age 70. The holder of many patents in computer systems architecture, he founded Teradata in 1979 and served as its chief technical officer. After joining the Caltech Board of Trustees in 2000, he reinvigorated Caltech's Career Advising and Experiential Learning center and assisted with the planning of the Hameetman Center and Bechtel Residence.

Endnotes

This year, the Earnest C. Watson Lecture Series turns 100. If you were to give a Watson Lecture, what would the title be, and why should people attend?

How an Academic Mother Studies Supermassive Black Holes with JWST

I will present the latest results from our JWST research program on the dusty cores of galaxy mergers, intertwined with the tales of a mother's experience in academia. Folks should attend if they want to hear about both exciting science done with the most powerful space telescope to date, as well as the human experience of the researcher involved.

Vivian U (BS '06)
IRVINE, CA

The Next Green Revolution"

I would talk about the need to reimagine the ways we get our food in the future. Can we feed 10 billion people using the agriculture and agricultural inputs we use now? What kind of environmental impact would that have? What can/should we be doing differently? How can chemists, biologists, and engineers help?

Seva Rostovtsev (PhD '01)
MEDIA, PA

Recognizing Courage: Why Caltech Should Establish a Prize for Courage in Science and Engineering

Courageous people are often written off as crazy … until they are not. Recognizing courage publicly defines the ways that scientists can "do the right thing" even when it is scary and/or difficult. Caltech has the stature and credibility to make these declarations and has a strong stake in a courageous scientific/engineering enterprise.

Gregg Wright (BS '69)
LINCOLN, NE

Human Augmentation

Recent developments may portend a kind of arms race as organic humans get new or enhanced abilities, possibly matching or exceeding AI. Is this scary hubris? An unleashing of diversity? Can it conceivably be stopped? A look at onrushing changes not yet in the headlines.

David Brin (BS '72)
SAN DIEGO, CA

What Does It Mean to 'Believe' in Science, and What's Wrong with the Converse?

We all hope we can make sure our futures are secure and comfortable and engaging. In this conversation, you and I will explore why the answer to the title question matters for this hope and what we, as a community, must figure out to sustain it.

Harrison Leong (PhD '86)
SAN FRANCISCO, CA

Alerting the Globe of Consequential Earthquakes

At Caltech, I began a 25-year effort to improve rapid earthquake shaking and loss assessments worldwide. The ingredients include the rapid characterization of the earthquake source and the spatial distribution of the shaking. Next, impact estimates require quantifying the exposure and vulnerability of buildings and the affected inhabitants. Lastly, communicating uncertain societal impacts requires careful consideration of their function and form.

David Wald (PhD '93)
EVERGREEN, CO

Embracing Complexity in Biological Systems

The human genome encodes 25,000 genes, but while all of a person's cells have the same DNA, complex networks of interacting elements make each cell type unique. In the same way, subtle differences in the DNA between individuals changes their networks, altering physical traits including disease risk and response to therapy. Increasingly, ideas borrowed from physics are shedding light on the complex processes by which our genes work to make us who we are.

John Quackenbush (BS '83)
DOVER, MA

The Watson Lectures 100

When Earth Breathed Deeply

Claire E. Bucholz
Assistant Professor of Geology

Wednesday, January 18, 2023
7:30 p.m. • Beckman Auditorium

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Caltech magazine

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“Synthetic” Mouse Embryos

Researchers from the University of Cambridge and Caltech have created model mouse embryos from stem cells—the body’s master cells that can develop into almost any cell type in the body—that have beating hearts and the foundations for a brain and all of the other organs in the mouse body. The results are the culmination of more than a decade of research, and they could help researchers understand why some embryos fail while others go on to develop into a fetus as part of a healthy pregnancy. Additionally, the results could be used to guide repair and development of synthetic human organs for transplantation. The research was conducted in the laboratory of Magdalena Zernicka-Goetz, Bren Professor of Biology and Biological Engineering at Caltech.

Find out more: