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Catalyst

SPRING/SUMMER 2023 VOLUME 18 • ISSUE 1
COLLEGE OF CHEMISTRY • UNIVERSITY OF CALIFORNIA, BERKELEY

Carolyn Bertozzi's path to the Nobel Prize

- Dean Toste next Chemistry Department Chair
- DEI Scholar introduces new science ethics course

Catalyst

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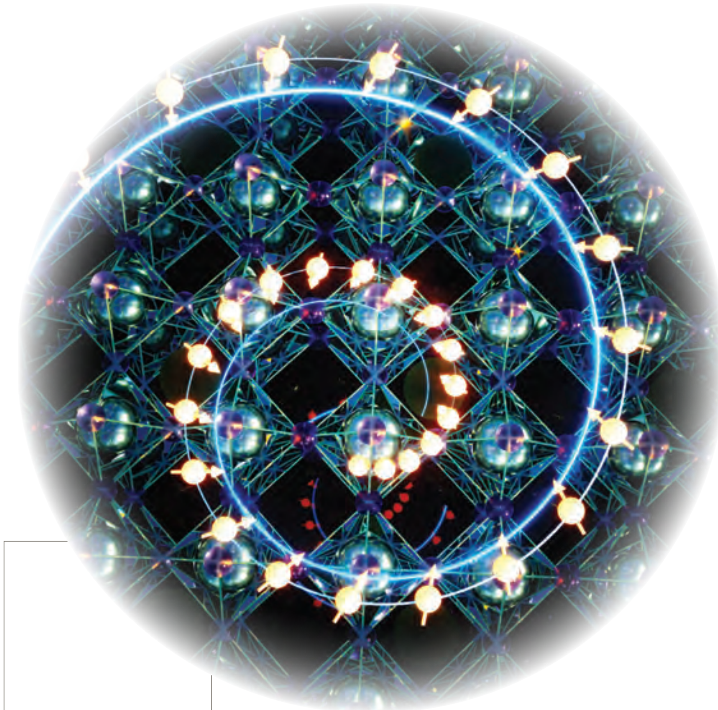
ON THE COVER

Carolyn Bertozzi photographed for the National Academies: New Heroes series

PHOTO BY CHRISTOPHER MICHEL



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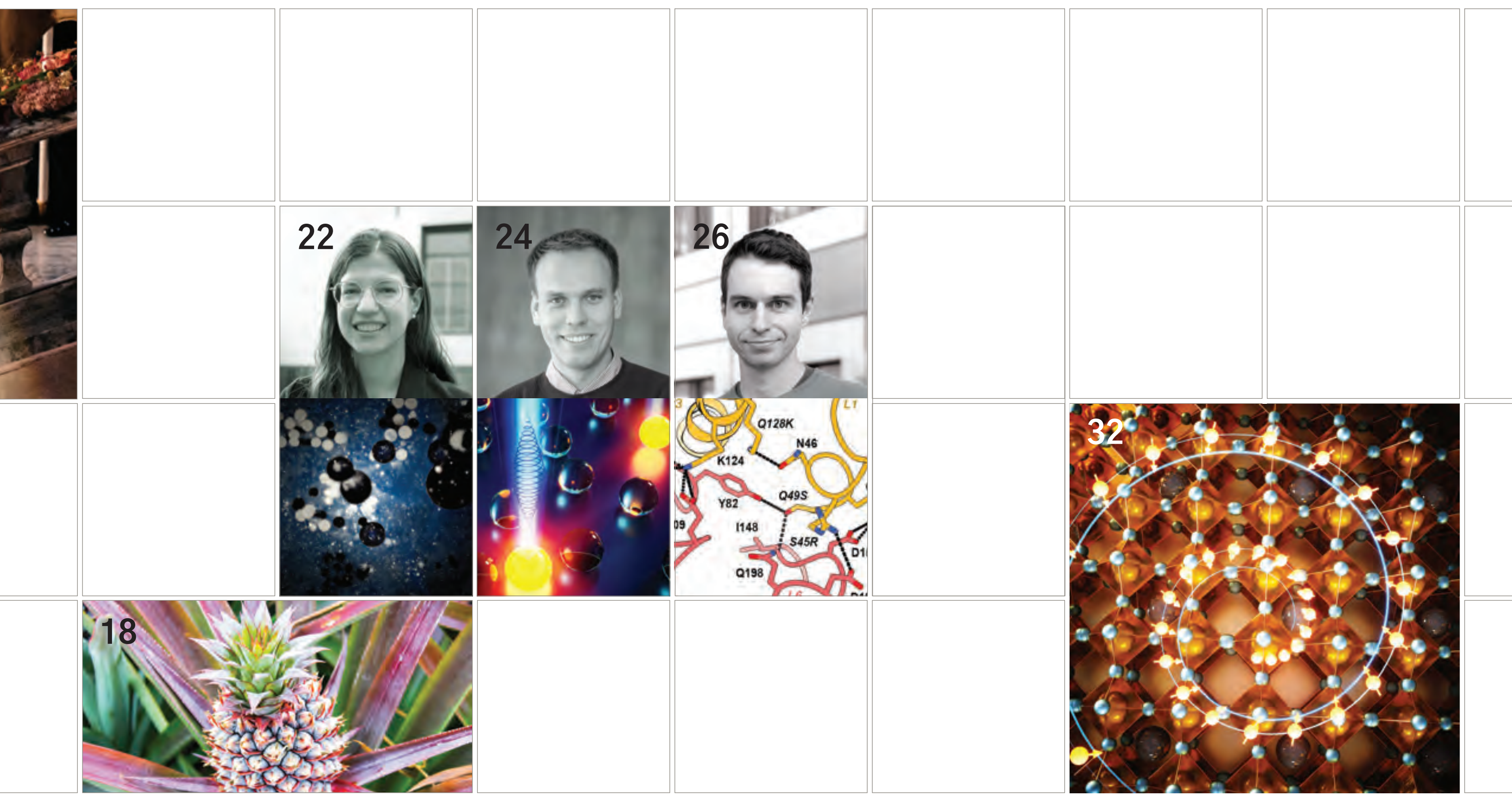



ROLYN R. BERTOZZI
Nobel Prize in Chemistry 2022

Much to celebrate

The end of the spring semester is always a busy and exciting time in the College of Chemistry, and this year was no exception. Soon-to-be-graduates donning hard-earned regalia and big smiles emerged in the nearby Hearst Mining Circle capturing photos with classmates and friends. In late April, I hosted our first Dean's Dinner since 2019. And we continued to celebrate the incredible achievements of our faculty and students.

On that note, we recently had the huge honor of raising a glass to Carolyn Bertozzi, our former colleague and 2022 Nobel Laureate in Chemistry, as she unveiled her Nobel plaque in the lobby of Latimer Hall. Her groundbreaking research minted her as the college's 18th Nobel Laureate and our 3rd woman Nobel Laureate, alongside Jennifer Doudna and Frances Arnold. How amazing is it that no other college on Earth can make that claim?

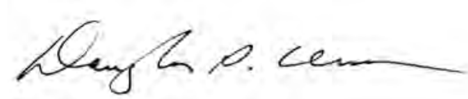
We welcomed five new assistant professors to the college during academic year 2022-23: Ziyang Zhang (chemical biology, who was highlighted in the last issue of *Catalyst*), Hendrik Utzat (physical chemistry), and Jennifer Bergner (physical chemistry) in the Department of Chemistry; Aditi Krishnapriyan (machine learning/AI) in the Department of Chemical & Biomolecular Engineering; and Robert Saxton (chemical biology) jointly in the Departments of Molecular & Cell Biology and Chemistry. We could not be more thrilled to have recruited these rising superstars; they are all truly exemplary and will further enhance our vibrant community of exceptional teachers and researchers.

After five intense and dedicated years, Matt Francis will step down as Chair of the Department of Chemistry at the end of June. During his tenure as Chair, Matt was successful in hiring eight (and counting) new faculty members, and he worked closely with graduate students to develop a Chemistry Climate Survey, highlighting the importance of diversifying chemistry faculty, improving graduate student mentorship, and addressing student mental health challenges. Matt also showed exemplary leadership navigating the unprecedented challenges posed by the pandemic. The college is indebted to Matt for his outstanding service.

Taking the reins from Matt is synthetic organic chemist Dean Toste, whose current research is primarily focused on the development and study of catalysts, catalytic reactions, and methods to address challenges in chemical synthesis and energy. Dean is a Member of the National Academy of Sciences and a Fellow of the American Academy of Arts and Sciences and the Royal Society of Canada – Academy of Science. I look forward to teaming up with Dean in his new administrative position in the college.

I would be remiss if I did not mention our progress on Heathcock Hall. With generous gifts totaling nearly $75M dollars in private philanthropy, $30M from the state, and an additional $30M in lending support from campus, we have reached a new milestone in our fundraising goal, and we are roughly $15M shy of our $150M goal to break ground before the end of this year. Thank you for your continued support, encouragement, and investment in the future of chemistry and chemical engineering research and education.

I hope you will enjoy reading about the many other noteworthy CoC developments and stories in this issue, including the new lectureship honoring Judith Klinman, the alumni feature on Ifan Lin, and Kevan Shokat's recognition for his high-impact cancer research and discoveries. I remain grateful and feel incredibly lucky that I get to engage with this dynamic and inspiring community each and every day.



DOUGLAS S. CLARK
Dean, College of Chemistry , Gilbert N. Lewis Professor

Carolyn Bertozzi and Douglas Clark join in a toast to celebrate the unveiling of her Nobel plaque in Latimer Hall, April 27, 2023.

BRITTANY HOSEA-SMALL

Dean Toste to become Chair of the Department of Chemistry in July

BY MARGE D'WYLDE

The College of Chemistry is delighted to announce that Dean Toste will serve as the next chair of the Department of Chemistry, effective July 1, 2023. He will step into the roll after Matthew Francis who has been Chair for the last five years. We are very grateful for Matt's exemplary service during that time.


YAHYA CHAUDHRY, HARVARD UNIVERSITY

Dean Toste on the occasion of delivering the Max Tishler Prize lecture at Harvard.

Dean was born in 1971 in Terceira, Azores, Portugal. He moved to Canada with his family as a young boy. While at the University of Toronto, he majored in chemistry and biochemistry and went on to obtain an M.Sc. in Organic Chemistry. He received his Ph.D. with Barry Trost at Stanford in 2000 and then went to a post-doctoral appointment with Robert Grubbs at Caltech.

Dean has been a member of the chemistry faculty since 2002, when he was appointed assistant professor by then-chair Judith Klinman. As a world-renowned synthetic organic chemist, his current research primarily focuses on the development and study of catalysts, catalytic reactions, and methods to address challenges in chemical synthesis and energy. During his time at Berkeley, over 50 Ph.D. students, more than 100 post-doctoral fellows, and numerous undergraduate students have been part of the Toste lab. He is a Faculty Scientist in the Chemical Sciences Division at Lawrence Berkeley National Laboratory and holds the Gerald K. Branch Distinguished Professorship in Chemistry.

Dean is a Member of the National Academy of Sciences (2020), a Fellow of the American Academy of Arts and Sciences (2018), and Fellow of the Academy of Science of the Royal Society of Canada (2015). Among his many honors, he has received the Humboldt Research Award (2016), American Chemical Society, Creativity in Synthetic Organic Chemistry Award (2015), and a UC Berkeley Miller Professorship (2014) to name just a few.

Dean is a member of the Novartis-Berkeley Translational Chemical Biology Institute which combines Novartis expertise in chemical biology and medicinal chemistry with Berkeley's expertise in covalent chemoproteomics and chemistry methodologies.

COURTESY OF DEAN TOSTE.

Dean Toste (center front row) photographed with former and current group members in August 2022. Photo was taken on campus during a symposium celebrating the 20th anniversary of the Toste Lab.

The Institute is intended to create collaborations aimed at unlocking intractable drug targets, discovering new therapeutic modalities, and accelerating discovery of new medicines in human diseases. Dean's UC Berkeley coresearchers at the Institute include Daniel Nomura (Institute Director), Thomas Maimone, Ziyang Zhang, and James Olzmann.

Dean's service to the campus community has also been admirable. He played an instrumental role as a member of UC Berkeley's Research Recovery Committee, which was established in response to the COVID-19 pandemic, leading campus recovery efforts in physical/chemical sciences research.

To learn more about Dean's research, please visit http://www.cchem.berkeley.edu/toste/.

NEW & NOTABLE

RESEARCH • VIEWS
DISCOVERIES • AWARDS

Chemical Engineering students compete with chemical designed cars

We are celebrating the awesomeness of our undergraduate Chemical Engineering students! This year's ChemE car team had two cars in the competition at UC San Diego. Our cars placed third (car name: Carthik Shekcar) and fourth (car name: Moy Moy Meadows)! Carthik Shekcar will go on to compete in the nationals. Not to brag too much, but we also placed 1st (Inji Park), 2nd (Prisha Davda and Cecilia Lau), and 3rd (William Wei) in the individual poster competition. Congratulations to everyone on the team for all your hard work. We are very proud of you.

Tiny microbes could brew big benefits for green biomanufacturing

A team of scientists from the College of Chemistry and Berkeley Lab, including Jay Keasling, John Hartwig, and Douglas Clark, have made a discovery that could reduce greenhouse gas emissions from the manufacturing of fuels, drugs, and chemicals. Specifically, the team is looking at a metabolic process in bacteria that could be a sustainable source of carbon-based products for industry. View the research at https://chemistry.berkeley.edu/biomanufacturing

Nobel chairs

In keeping with the fun tradition started in 2001, Nobel laureates Carolyn Bertozzi, Jennifer Doudna, and David Macmillan signed bottoms of chairs at the Nobel Prize Museum. The tradition is believed to have started with former U.S. President and philanthropist Bill Clinton (who has not won a Nobel prize) attending the museum's opening in 2001 and spontaneously signing the bottom of a chair without being asked. The tradition has carried on with Nobel laureates since. An added bonus is that Jennifer Doudna and Carolyn Bertozzi's signatures are right next to each other.

Jeffrey Reimer awarded the Berkeley Citation

Professor of the Graduate School Jeffrey Reimer has been honored with the Berkeley Citation. Prof. Reimer was presented the award by Chancellor Carol Christ during the G.N. Lewis lecture where Prof. Reimer was the guest speaker.

Professor Reimer's work has generated new knowledge for environmental protection and sustainability, and providing fundamental insights to condensed matter through materials chemistry, physics, and engineering for over 40 years at Berkeley. He is the recipient of a Camille and Henry Dreyfus Teacher-Scholar Award, the AIChE Northern California Section Award for Chemical Engineering Excellence in Academic Teaching, the Donald Sterling Noyce Prize for Excellence in Undergraduate Teaching, the CBE Department Teaching Award (in 2000 and 2015), and the UC Berkeley Distinguished Teaching Award in 2003.

For his remarkable research achievements, Professor Reimer has been honored as a Fellow of the American Association for the Advancement of Science, the American Physical Society in the Division of Materials Physics, and the International Society for Magnetic Resonance among other honors.

Lectureship established in honor of Judith Klinman

Thanks to the generosity of four alumni who did their research in the lab of Judith Klinman, a new College lectureship has been established in her honor. Alumni Susan Miller (Ph.D. ’83, Chem), Sophie Wang (Ph.D. ’90, Chem), Natalie Ahn (Ph.D. ’85, Chem), and Roseanne Wincek (B.S. ’04, Chem) wanted to celebrate the community that Judith has built over her time at Berkeley and the impact that she has had on her students. Susan, Natalie and Sophie were the first and second graduate students, and the first foreign graduate student from China, to receive Ph.D.s in Judith’s lab. Roseanne was one of the few undergraduate students who did research with Judith.

Sophie Wang announced the lectureship at the 80th birthday symposium held in Judith’s honor last year. “Judith was such an incredible role model for us inspiring the men and women in her lab. It has been so wonderful to have her in our lives,” Sophie said.

Susan Miller agreed, “We have all been so inspired by Judith. We appreciate her scientific rigor, and the challenge and curiosity she shared with us. We wanted to create this lasting acknowledgement in perpetuity to honor and recognize her tremendous contributions to science and mentorship bringing so many people into the scientific world.”

Judith is known for her research on enzyme catalysis. She was the first female professor to join the physical sciences at UC Berkeley in 1978, where she is now Professor of the Graduate School and Chancellor’s Professor. In 2012, she was awarded the National Medal of Science by President Barack Obama which is the highest scientific honor bestowed by the United States.

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“I arrived at UC Berkeley in 1978 as the first woman in the physical sciences .... Over the many years that I have been pursuing science, my laboratory has made observations that go against mainstream thinking. I have had to learn to trust my intuition and stick to my guns!”

—JUDITH KLINMAN

3

4

Clockwise from top:

1 Sophie Wang with Judith.

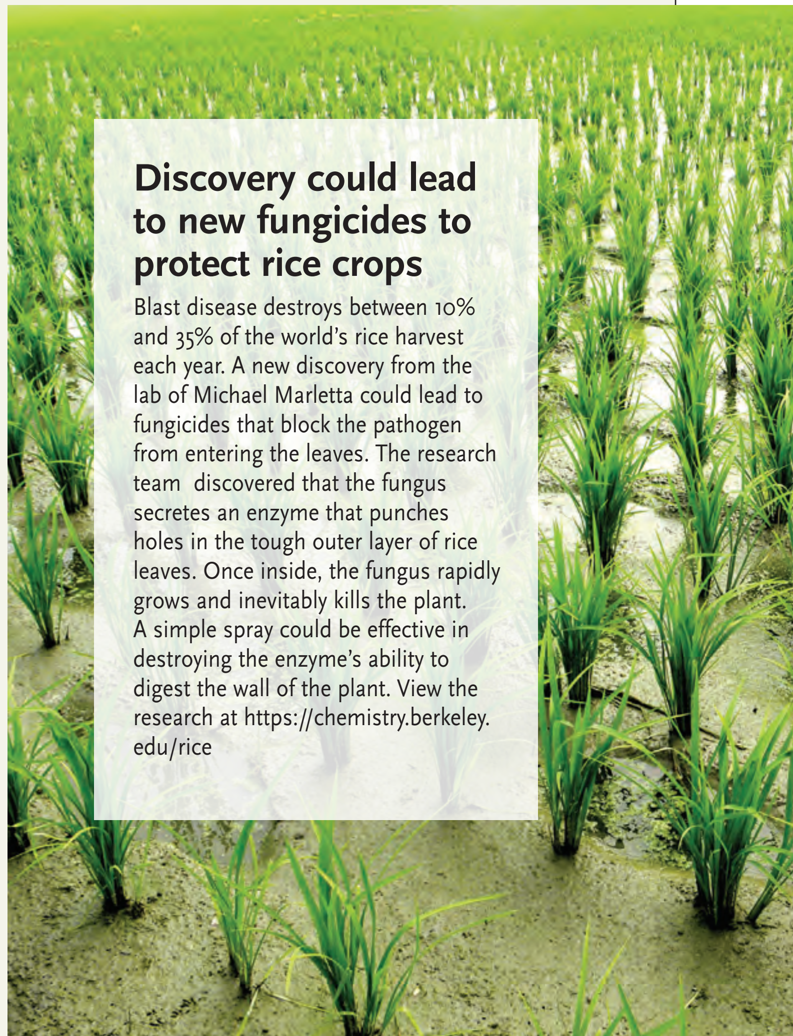
2 Roseanne Wincek in the blue shirt, third from right.

3 Judith with Natalie Ahn when Natalie was inducted into the National Academy of Sciences in 2018.

4 The early days at the lab:
Front row (l to r): Susan Miller, Judith Klinman, Matt Krueger. Back row (l to r) Julie Bertolucci, Monica Palcic, Jim Mangold, and Marty Farnum.

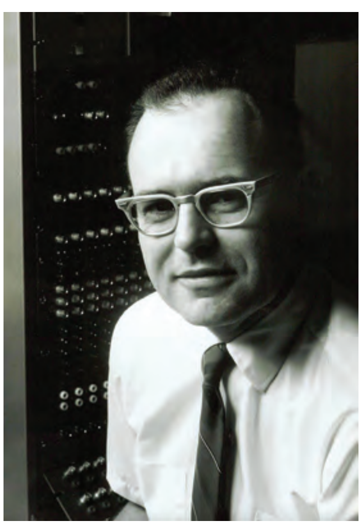
Newest College members of the National Academy of Sciences

Congratulations to Jeffrey Long, Professor of Chemistry and Chemical and Biomolecular Engineering and T. Don Tilley, the PMP Tech Chancellor's Chair in Chemistry, who were among the 120 new members and 23 new international members elected to the National Academy of Sciences (NAS) announced in May. NAS was established by an Act of Congress, signed by President Abraham Lincoln, in 1863. The NAS is charged with providing independent, objective advice to the nation on matters related to science and technology. The NAS is committed to furthering science in America, and its members are active contributors to the international scientific community.



Discovery could lead to new fungicides to protect rice crops

Blast disease destroys between 10% and 35% of the world's rice harvest each year. A new discovery from the lab of Michael Marletta could lead to fungicides that block the pathogen from entering the leaves. The research team discovered that the fungus secretes an enzyme that punches holes in the tough outer layer of rice leaves. Once inside, the fungus rapidly grows and inevitably kills the plant. A simple spray could be effective in destroying the enzyme's ability to digest the wall of the plant. View the research at https://chemistry.berkeley.edu/rice



IN MEMORIAM

Alumnus Gordon Moore (1929 – 2023)

Alumnus Gordon Moore (B.S. '50, Chem) passed away March 24, 2023. Moore was a groundbreaking technician, thoughtful philanthropist, and self-described "accidental entrepreneur," who is perhaps most widely known for his 1965 prediction that the number of transistors that can fit on a silicon chip would double approximately every two years. A founder of Fairchild semiconductor and Intel, Moore was a central figure in the technology revolution that transformed computers from room-sized-punch-card-reading machines to the lightweight devices we have come to rely on.

CAROLYN BERTOZZI'S PATH TO THE NOBEL PRIZE

In a year unlike any other in the history of UC Berkeley, four chemistry Nobel laureates affiliated with the College of Chemistry, three of them women, sat on the stage in Stockholm, Sweden during the Nobel medal ceremony on December 8, 2022.

NANAKA ADACHI, 2022

NOBEL MEDAL CEREMONY STOCKHOLM, SWEDEN

Gracing the front row was Carolyn Bertozzi (Ph.D. ’93, Chem) and former College faculty member (1996-2015). Currently at Stanford University, she waited with the rest of the 2022 recipients to receive her prize from King Carl XVI Gustaf of Sweden. Carolyn was recognized for her development of bioorthogonal chemistry. (Fourth from left)

In the second row was David MacMillan, a former faculty member (1998-2000), who had received the Nobel Prize in Chemistry for the development of asymmetric organocatalysis in 2021. (Second row sixth from the right.)

Behind Carolyn, in the top row far left, alumna Frances Arnold (Ph.D. ’85, ChemE and faculty member at CalTech) who had received the prize in 2018 for the directed evolution of enzymes. Frances had been invited to speak on the future of life during the Nobel week program ‘Dialogue 2022’.

And Jennifer Doudna, UC Berkeley’s Li Ka Shing Chancellor’s Professor of Biomedical Science, and professor of chemistry and biochemistry and molecular biology, in the back row third from the right next to co-winner Emmanuel Charpentier, who had been awarded the Nobel Prize in Chemistry in 2020 for the development of a method for genome editing.

BY ROBERT SANDERS

Carolyn Bertozzi, a professor at Stanford University recognized with the Nobel Prize in Chemistry on October 5, 2022, spent her formative and most creative years at UC Berkeley.

After graduating from Harvard University in 1988, she earned her Ph.D. in chemistry from Berkeley in 1993 and, following postdoctoral and faculty positions elsewhere, returned to join the chemistry faculty and Berkeley Lab in 1996.

For 19 years, until 2015 — the year she left to help lead Stanford's Sarafan ChEM-H institute — she developed at Berkeley the chemical biology techniques for which she received the Nobel Prize. She calls these techniques bioorthogonal chemistry, building off the "click chemistry" developed by her Nobel Prize co-winners, K. Barry Sharpless of Scripps Research in La Jolla, California, and Morten Meldal of the University of Copenhagen in Denmark.

"Carolyn Bertozzi is a true trailblazer in chemical biology," said Doug Clark, dean of the College of Chemistry. "Her lab is among the most prolific in the field, consistently producing innovative and enabling chemical approaches, inspired by organic synthesis, for the study of complex biomolecules in living cells. Carolyn's work and spirit embody what is best about the scientific tradition and history of the College of Chemistry and of UC Berkeley."

Carolyn Bertozzi is now the Anne T. and Robert M. Bass Professor in the School of Humanities and Sciences and a professor of chemistry at Stanford University.

During a video press conference, the morning the prize was announced from Stanford, Bertozzi, 55, described bioorthogonal chemistry as chemical reactions "not interacting with or interfering with biology."

"What that means in practice is that we basically develop pairs of chemical groups, and those pairs of groups are perfectly suited for each other," she said. "And when they encounter each other, they want to react and form a bond, and they love each other so much that you can surround those chemical groups with thousands of other chemicals — that's what you have in biological systems, in your cells, in your body, there's thousands of chemicals — but these two chemicals that are bioorthogonal will ignore all of that. And they'll find each other and form a bond with each other, do chemistry with each other."

Bertozzi's rationale for developing these reactions was to study the sugars that coat the outside of cells — a field called glycobiology — that has been a passion of hers since her graduate student days at Berkeley. At Berkeley, she worked in the lab of Mark Bednarski, a young assistant professor and a rising star in the field of chemical biology, at the time a relatively new field in which the biochemical processes inside cells are manipulated and studied using techniques of organic chemistry.

In a 2011 campus interview, Bertozzi discussed the role Berkeley played in her career. "I credit the UC Berkeley environment for catalyzing my interests in chemical biology and glycobiology from the outset, as I first learned about the opportunities in these fields as a graduate student in this very department," she said. "I was encouraged to join the lab of a new professor, Mark Bednarski, and he introduced me to the chemistry and biology of sugars. I have been enraptured by this still-burgeoning area of science ever since, in light of the critical roles that sugars play in cell signaling, organ development, immunobiology and in numerous diseases."

A friend and former colleague of Bertozzi's at Berkeley, Matt Francis, now chair of the Department of Chemistry, was one of the first to congratulate Bertozzi after the streamed announcement from Stockholm at 2:45 a.m. PDT, which he was watching. He immediately texted her congratulations.

"As soon as I heard her name in Swedish, I sent it, and I got an emoji back immediately — the shocked face emoji," he said. "She's a total rock star, and this is well deserved."

Francis came to Berkeley in 2001, when Bertozzi was already well known for her research, and she was a critical academic mentor, he said.

"She did more than just do great science. She really mentored a lot of us who are on the faculty now and helped us get our groups off the ground and was always there to talk to us," he said. "She was just a great colleague."

She is equally known for mentoring students at both Berkeley and Stanford. The College's chemical biology degree was developed in conjunction with significant contributions from Ken Sauer and Judith Klinman. Michael Marletta was also important for the graduate program in chemical biology as the co-director.

During the Stanford press conference, Bertozzi explained what led to her Nobel Prize-winning work.

Carolyn photographed for the NAS New Heroes Series

CHRISTOPHER MICHEL, 2022

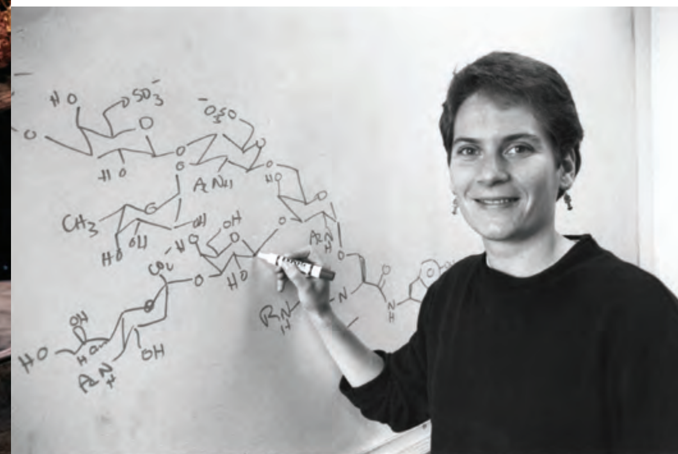
Carolyn speaks at the Nobel Banquet.

"Bioorthogonal chemistry was a tool that my lab created originally to study cell surface sugars — in fact, to image cell surface sugars using microscopes," she said. "But then, it turned out to be so useful just as a platform for studying biology that lots of other labs picked up on it and started using those same chemistries to study other molecules, like proteins DNA and RNA. And they, and it turns out you, can study these molecules in live cells and in laboratory animals. And the most exciting development is now there's a pharmaceutical company doing these chemistries inside the body of human cancer patients as a means to deliver drugs to cancers. So, the field has really progressed a long way in the last 25 years, and it's very exciting for me to see this."

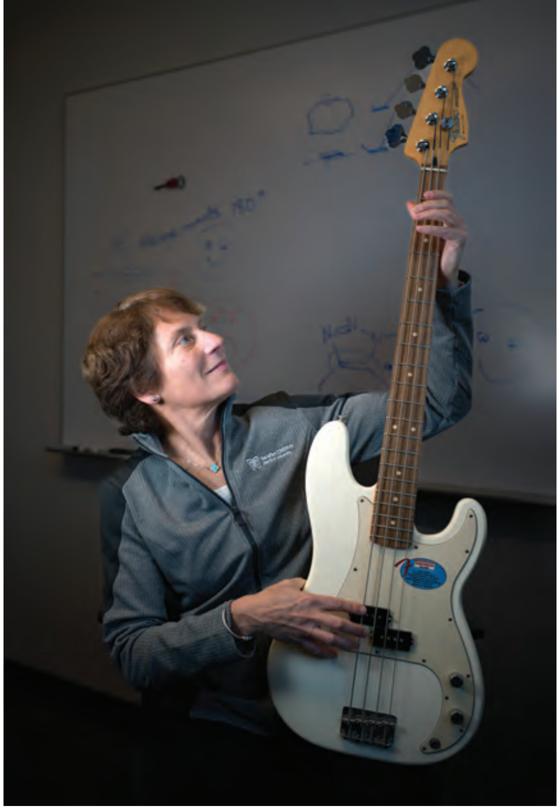
She emphasized that her work built on that of Nobel co-winners Sharpless and Meldal.

"Before the advent of bioorthogonal chemistry and the related chemistry that professors Sharpless and Meldal developed, which they call click chemistry, there was really no way to study certain biological processes. They were just invisible to the scientists," she said. "But these chemistries make those processes visible, and we have benefited from that — specifically, to study cell surface sugars."

The click chemistry reactions Sharpless and Meldal developed involved copper however, which is often toxic to living cells. According to Francis, Bertozzi found a novel way around using copper.



Photos of Carolyn at UC Berkeley circa 1996-7.



CHRISTOPHER MICHEL, 2022

CLÉMENT MORIN, 2022

(Top) Carolyn with her guitar photographed for the NAS New Heroes Series; (right) Jennifer Doudna, Carolyn Bertozzi, and Frances Arnold in Stockholm, Sweden.

"Carolyn's lab came up with a way around it where they built strain into one of the molecules. In other words, they spring-loaded that molecule so it made it much more readily reactive without the copper," he said. "And that is now what most people use to label live cell surfaces. It's called strain promoted click chemistry. She really changed the way people think about the chemistry that we could do in a living organism."

Francis said that copper-based click chemistry is arguably still faster and is used today in situations without living cells, but Bertozzi's copperless click chemistry — as well as her previous work on the Bertozzi-Staudinger ligation — is the only technique that works in living cells.

Much of her research while at Berkeley was done in collaboration with scientists at Berkeley Lab. She was one of six Berkeley Lab scientists who led the establishment of the Molecular Foundry, a nanoscience research facility that provides scientists from around the world with access to cutting-edge expertise and instrumentation, and she served as its director from 2006 until 2010.

"It was a privilege to watch how the success of her (Bertozzi's) discoveries unfolded here on the Berkeley campus and beyond," said Clark, who also is a faculty scientist at Berkeley Lab. "On behalf of the College of Chemistry community, we extend our heartiest congratulations to Carolyn for her spectacular work and this well-deserved honor."

CELEBRATING OUR THREE REMARKABLE WOMEN NOBEL LAUREATES

The Nobel Prize in Chemistry has been awarded 114 times to 191 Nobel Prize laureates since 1901. Eight of those awards have been given to women. Starting in 2018, three brilliant women scientists affiliated with UC Berkeley have won the award.

Professor Frances Arnold (Ph.D. '85, ChemE) at CalTech was first in 2018. She was also the first Ph.D. Chemical Engineer to receive the prize in Nobel history. She was awarded the prize for the directed evolution of enzymes.

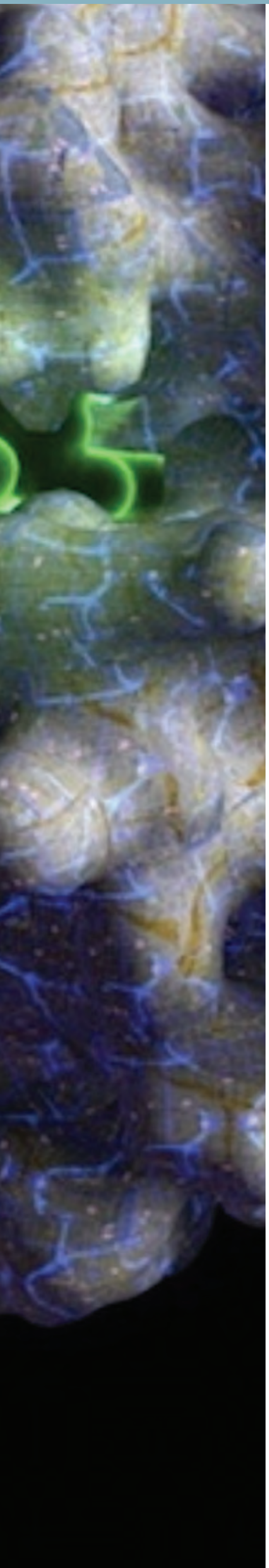
Next was Jennifer Doudna, UC Berkeley Li Ka Shing Chancellor's Professor of Biomedical Science, and Professor of Chemistry and Biochemistry & Molecular Biology who received the award in 2020 with colleague Emmanuel Charpentier for the development of a method for genome editing.

And then last year, Professor Carolyn Bertozzi (Ph.D. '93 Chem) currently at Stanford and formerly at UC Berkeley (1996-2015), received the prize for her development of bioorthogonal chemistry.

And in an absolute first, the lovely photo you see above is of the three women together in December 2022 at the celebration of Nobel laureates in Sweden.

Alumni creativity on display

Our alumni leave the College moving into a remarkable variety of academic, industrial, and entrepreneurial professions. Many of our students pursue graduate degrees and postdoctoral appointments to explore academic careers and more advanced scientific research. Others go straight into industry with a B.S. or B.A. degree.



BY ROBIN MARKS

Science world honors **Kevan Shokat** for high-impact cancer research

The UC San Francisco scientist who developed a successful approach to drugging a protein produced by the mutated KRAS gene has won two prestigious awards in the opening weeks of 2023. The discovery, made by Kevan Shokat (Ph.D. '91, Chem), in 2013 opened up new avenues for cancer treatment and research.

Mutations in the KRAS gene, which drive 30% of human cancers and are the culprits behind many challenging-to-treat lung, colon, and pancreatic tumors were deemed "undruggable" for decades until Shokat found a pocket in one mutated protein's shape where he could lodge a drug.

Last month, Shokat, a professor of cellular and molecular pharmacology, was recognized by the National Academy of Sciences (NAS) with the organization's annual Award for Scientific Discovery – given for pioneering breakthroughs in chemical biology to advance cancer therapy. He received $50,000 in prize money and another $50,000 to support his research.

In a statement, the NAS called Shokat "a pioneer of modern chemical biology, using innovative approaches to develop powerful molecular tools to advance basic knowledge and combat devastating diseases."

More recently, Shokat was also honored as the recipient of the Sjöberg Prize from the Swedish Academy of Sciences, the same body that awards the Nobel prizes for physics, chemistry and economics.

Shokat's work heralds "the start of an entirely new era, in which we will build upon this initial discovery," said Urban Lendahl, PhD, a member of the Prize Committee and professor of genetics at Karolinska Institutet.

The Sjöberg Prize was established in 2017 using a donation from businessman Bengt Sjöberg, who died from cancer in 2017. The aim is to promote scientific research that primarily focuses on cancer, health and the environment. Winners receive $100,000 as a personal prize and $900,000 for continued research.

The first recipient of the Sjöberg prize was James Allison, PhD, who had a faculty appointment at UCSF 20 years earlier. In 2018, he received the Nobel Prize in Physiology or Medicine. Other past prize recipients have been recognized for developing revolutionary treatments and furthering our understanding of the molecular and cellular biology that underpins cancer.

"I feel so fortunate to receive the Prize for Scientific Discovery and the Sjöberg Prize for my lab's work on identifying a path towards drugs to treat KRAS-mutant cancers," said Shokat, reflecting on the back-to-back prizes. "The pace of KRAS drug discovery is moving so fast now that our assumptions about what seems possible are changing month-by-month."

Shokat was encouraged to tackle the challenge of KRAS genes by colleague Frank McCormick, PhD, FRS, DSc (Hon), the David A. Wood Distinguished Professor of Tumor Biology and Cancer Research. McCormick is now head of the National Cancer Institute's RAS Initiative, which was established the same year Shokat made his discovery, and dedicated creating effective, new therapies for RAS-related cancers.

Their range of scientific pursuits is breathtaking. In this feature we look at three of our amazing alumni and their career trajectories. Learn about Kevan Shokat who is pursuing novel solutions to cancer treatments; Ifan Lin whose family company in Taiwan develops biochemical products using all natural materials; and Rebecca Dylla-Spears who does fascinating discovery research at Lawrence Livermore National Lab.

"The pace of KRAS drug discovery is moving so fast now that our assumptions about what seems possible are changing month-by-month." —**KEVAN SHOKAT,** Ph.D.

"Without Frank, we wouldn't have pursued this so vigorously," Shokat said.

Shokat was elected to both the NAS and the National Academy of Medicine in 2009. He received his undergraduate degree from Reed College in 1986 and his Ph.D. in organic chemistry in 1991 from UC Berkeley, where he holds an appointment in the Department of Chemistry. He is also a Howard Hughes Medical Institute investigator and a member of USCF's Helen Diller Family Comprehensive Cancer Center.

> "I consider myself lucky to have had Ifan in class and working in my lab, and I'll always remember his enthusiasm and excitement for learning. He still has that same sparkle, and what he has accomplished for the benefit of so many people is really inspiring."
> —**DOUGLAS CLARK,** Dean, College of Chemistry

BY MARGE D'WYLDE

Ifan Lin: From farm to pharma – the challenges of producing a botanical drug

Ifan Lin (B.S. '06, ChemE) got a lot out of his time at UC Berkeley. Born and raised in Taiwan, Ifan and his sister (Irene) spent their junior and high school years in New Zealand. Ifan went on to UC Berkeley to do his undergraduate degree in chemical engineering where he spent time in the lab of the College's dean Douglas Clark. He continued to Stanford for graduate studies, receiving his M.S. degree before being called home to help with the family business.

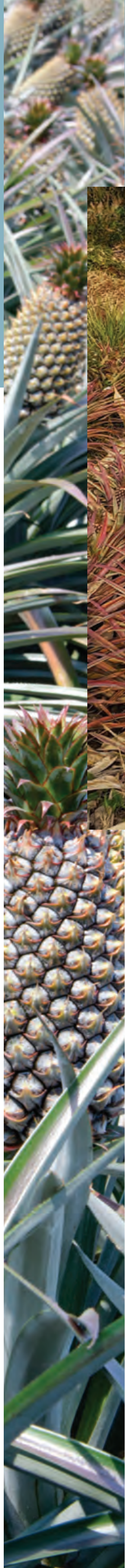
"I planned to finish my Ph.D. at Stanford, but my father had some health issues that were interfering with a company expansion at the time. The company was preparing for the implementation of a major enzyme project which included U.S. FDA and European Union inspections. The whole facility needed to be upgraded. I eventually received my Ph.D. from National Chung Hsing University," Ifan explains.

The company is Challenge Bioproducts Co. Ltd. (CBC) located in Taiwan. CBC is extracting Bromelain (cysteine proteases) from pineapple stems for human and animal uses. Bromelain promotes human and animal's health by aiding digestion and reducing inflammation, thus it is popular as a natural dietary supplement and feed additive. In the meantime, company founder and Ifan's father CK Lin, was working with Dr. Gerold Klein in the U.S. on research looking at enzymatic debridement for a burn treatment. Enzymatic debridement has become a successful replacement for some surgical debridement procedures with excellent results.

"The Bromelain we produce from our specific pineapple stems has a very high concentration of protease which is excellent at digesting proteins. It is also a mixture of a lot of different enzymes. Dr. Klein discovered that one of the enzymes was able to differentiate between dead and viable tissue. There are several protease extractions that have been tested including papaya and kiwi fruit. None of them have been as successful as our Bromelain since they would digest viable tissues as well as the narcotic tissue in tests," Ifan says.

Dr. Klein wanted to join forces with CBC since he did not have a pharmaceutical manufacturing facility to handle the project. His hope was CBC would start by applying in Taiwan for regulatory approval. The company tried but the Taiwanese authorities at the time thought a botanical enzymatic drug was too novel, so they suggested CBC should seek approval in the U.S. or Europe, before filing in Taiwan. In 2000, MediWound was specifically founded for this project by Dr. Lior Rosenberg and Dr. Marian Gorecki. CBC is the Bromelain supplier for their drug NexoBrid®

NexoBrid® received its first regulatory approval in Europe in 2012 for use with burn victims. The U.S. FDA approved NexoBrid® in 2022 as the first botanical drug approved for burn treatment. "I would consider us lucky because at the time, the main jurisdiction that handled the project for Europe was the German authority. Germans are very positive about using natural ingredients and thus more favorable toward their use in pharmaceuticals. This is the opposite of the U.S. FDA, which prefers to see chemical compounds that can be duplicated exactly batch after batch. To be approved, we had to do many additional studies to prove that our product was refined enough to be consistent



COURTESY IFAN LIN

Ifan Lin (right) stands in front of a field of pineapples in Taiwan with his family (l to r) parents CK Lin and Beatrice Lee and sister Irene Lin.

in the United States. It's all about concerns of contamination and showing that a natural product can be as reliable as manufactured chemical ingredients."

To date, NexoBrid® has been approved in 44 countries and has been used as a treatment for more than 11,000 patients.

"I look back on my time at Berkeley and think about some of the experiences that I had there and how they have helped me throughout my life. I really enjoyed immersing myself in American culture. I was trying to develop my own identify beyond being a Taiwanese national from New Zealand. At Berkeley, there were a lot of free-thinking spirits. I made a lot of friends who certainly were. The internet was there, but not as popular as now, with people checking their smartphones every five minutes. I got a lot of information directly from my peers at Berkeley," Ifan remarks.

He continues, "I was also fortunate to meet my wife Sophia Su (B.S. '06, ChemE) who was in the chemical engineering program. We joined the AIChE Club which was great. I was the club's webmaster. The club regularly sponsored industrial events which exposed us to different companies. Also, there were a couple of courses where the faculty invited someone from industry to talk to us about fermentation and the like. It may have been in Doug's class."

Ifan enjoyed Doug as a teacher and decided to do his junior research project in Doug's lab. "I chose Doug because he seemed very kind and open-minded. I really liked his teaching style – as though he was giving a talk instead of lecturing in a classroom. He was excellent at breaking concepts down and explaining them in detail," Ifan says.

Ifan continues, "I worked on an experiment in the lab with Doug's graduate student Umar Akbar. It turned out both Umar and Doug were somewhat hands off in the lab which I wasn't used to. But it made me realize that I needed to push myself and not wait for someone to tell me what to do next. I kept on with the experiments and asked for more if I had the time. Doug trusted his students to make the right decisions but was always there to consult with you when anything came up. It was a very good experience for me."

COURTESY OF LAWRENCE LIVERMORE NATIONAL LAB, 2004

Rebecca shows off a giant KDP crystal grown in the lab.

BY MARGE D'WYLDE

Rebecca Dylla-Spears: A front row seat to future science at Lawrence Livermore National Lab

Our third alumus in this series is chemical engineer Rebecca Dylla-Spears (Ph.D. '09, ChemE) who is a research scientist at Lawrence Livermore National Lab (LLNL). Rebecca received her Ph.D. with Professor of Chemical and Biomolecular Engineering Susan Muller and Chancellor's Professor Lydia Sohn in mechanical engineering.

Rebecca grew up in the small Texas farming town of St. Hedwig, outside of San Antonio where about 1,000 people lived when she was young. After high school, she went on to the University of Texas at Austin (UT) for joint undergraduate degrees in chemical engineering and liberal arts.

After UT, Rebecca came to California and worked for two years at Clorox in their R&D group. From there, she continued to LLNL working on potassium dihydrogen phosphate (KDP) crystal growth in the National Ignition Facility and Photon Science (NIF&PS) program.

"After I worked in the lab at LLNL for a while and saw the research opportunities, I decided I wanted to 'expand my toolbox' and went to UC Berkeley to get my Ph.D. in chemical engineering," Rebecca said. "I worked with Susan Muller and Lydia Sohn. My dissertation focused on the use of microfluidic stagnation point flows to trap and stretch DNA for detection of tagged sequences."

After graduation, Rebecca returned to LLNL. "I worked in the NIF&PS cryogenic deuterium-tritium (DT) layering program. Our experiments resulted in the process used to grow the DT crystal fuel layers required for inertial confinement fusion targets. Everyone at the lab was thrilled when fusion ignition was successfully achieved on December 5th, 2022, in a world first."

She continues, "Many generations of scientists contributed to this amazing success. Advances in lasers, optics, and targets were an important part of that. The work is far from done. Finding a solution to creating clean fusion energy in the future is of increasing urgency to the world. Getting to the next step in this grand scientific endeavor—toward sustainable fusion power plants—will require dedication, grit, hard work, and sustained investment."

Rebecca continues, "I worked on the DT layering project for five years. At the same time, I was also supporting optics research, which gave me experience in colloidal science, optical finishing, and fabrication. This encouraged me to move on to create a research program in additive manufacturing and optics. I became the principal investigator for a large, strategic R&D program to look at three different methods of making optics using additive manufacturing: one area was lightweight mirrors, one was gradient refractive index optics, and the third was graded composition gain media. It has been exciting work because research into glass additive manufacturing is relatively new in the last seven years, compared to other materials like polymers, metals and ceramics."

2021 COURTESY OF LAWRENCE LIVERMORE NATIONAL LAB. PHOTO GARRY MCLEOD.

Specifically, the team developed optical components with functionally graded material properties that resulted from changes to the optics' composition, not its shape. The optics are being produced using 3D printing technology with direct ink writing (DIW). After testing many processes, the team chose this approach because it gave them the most control over composition in three dimensions.

Rebecca enthuses, "We were honored in 2022 when our multi-disciplinary team of physicists, material scientists, chemists, chemical engineers, mechanical engineers, and optical engineers won an R&D 100 award (from R&D World Magazine) for development of the additive manufacturing process which we decided to call 'Tailored Glass Using Direct Ink Writing Technology'. This technology can be used to print silica-based optics and glass components with customizable forms and spatially varying material properties. The technology will enable fabrication of new kinds of optics."

Last year, Rebecca decided to pursue research in another unit at the Lab. "I like to go where my skills can best be used because I enjoy learning new things. I think it's important to not tell yourself 'No.' I'm now working with teams investigating a broader range of materials and manufacturing methods related to national security applications."

Rebecca continues, "Thinking back on it, my Ph.D. in chemical engineering taught me how to learn anything. With the skills I gained, I can dive into new subjects and become competent. And that has helped me because in my career here at the lab, I go where the need is. I'm the kind of person who likes to keep challenging myself in that way. I know, because I've done this multiple times now, that you can become knowledgeable in new subject areas without having the background to start with. Really, that is what my Ph.D. did for me. Having that confidence that a Ph.D. brings, earning it through hard work and diving into something brand new in the graduate lab, is really the thing that lets you know in your future that you're going to be okay."

JENNIFER BERGNER

Deep space chemistry

BY SARAH C.P. WILLIAMS

Millions of light years away from Earth, atoms collide and merge; chemical structures assemble and fall apart again. The same elements that built our planet float through outer space. Yet the reactions they undergo are quite different, thanks to the absence of gravity, the presence of high-energy radiation, and extreme temperatures and pressures.

By recreating these extraterrestrial chemical reactions in cryogenic vacuum chambers, Dr. Jennifer Bergner illuminates the chemical processes accompanying the formation of new planets, and how planets may become hospitable to life.

Bergner, who joined the College of Chemistry as an assistant professor in January 2023, is as likely to be found mixing chemicals in the lab as she is poring over the latest data from the James Webb Space Telescope (WEBB). She has come to Berkeley after a post-doctoral fellowship at the University of Chicago.

“This is an incredibly exciting time in the field of astrochemistry and I’m thrilled to be launching my lab here at Berkeley,” says Bergner. “Right now, we’re learning new things about planet formation at a very rapid pace.”

“CRAZY MOLECULES THAT SHOULDN’T EXIST”

Growing up in Virginia, Bergner always loved science. A great high school chemistry teacher helped her fall in love with the minutiae of chemical structures and reactions.

“Chemistry has provided me with these problems that are incredibly challenging but can be methodically worked out,” says Bergner. “Whenever I get an answer, or discover something new, I find it so rewarding.”

As a University of Virginia undergraduate, Bergner majored in chemistry and carried out research analyzing levels of pharmaceutical contamination in wastewater. Then, in her senior year, she went to a seminar given by the astrochemist Eric Herbst — who studies reactions that occur in outer space. It would change the trajectory of her career.

“I felt like I had just spent three and a half years learning what chemistry was, and then this scientist came in and started talking about all these crazy molecules that shouldn’t exist,” recalls Bergner. “But they do exist, because the chemistry is happening in these really exotic conditions.”

She was absolutely fascinated and, by the time she started her Ph.D. in Chemistry at Harvard, she had decided to pursue astrochemistry. She connected with an advisor in the Astronomy Department and began straddling the fields of astronomy and chemistry— something she has become increasingly adept at over the time.

FOCUSED ON ICE

Under the right physical conditions, molecules that never freeze on Earth— like O_2 and N_2— turn into solid ice. These conditions, it turns out, are ubiquitous elsewhere in the universe and some of the most pertinent chemistry that happens during planet formation occurs in mixed, condensed ices.

Early in graduate school, Bergner decided to focus her work on these ices. In the lab, she simulated conditions under which these ices could form. At the same time, she collected data from powerful spectroscopic telescopes that reported the conditions in far-away regions of space where stars and planets are forming.

Using this combination of approaches, she discovered— among other things— how excited oxygen atoms, formed when energetic radiation hit certain ices, could contribute to the formation of organic molecules.

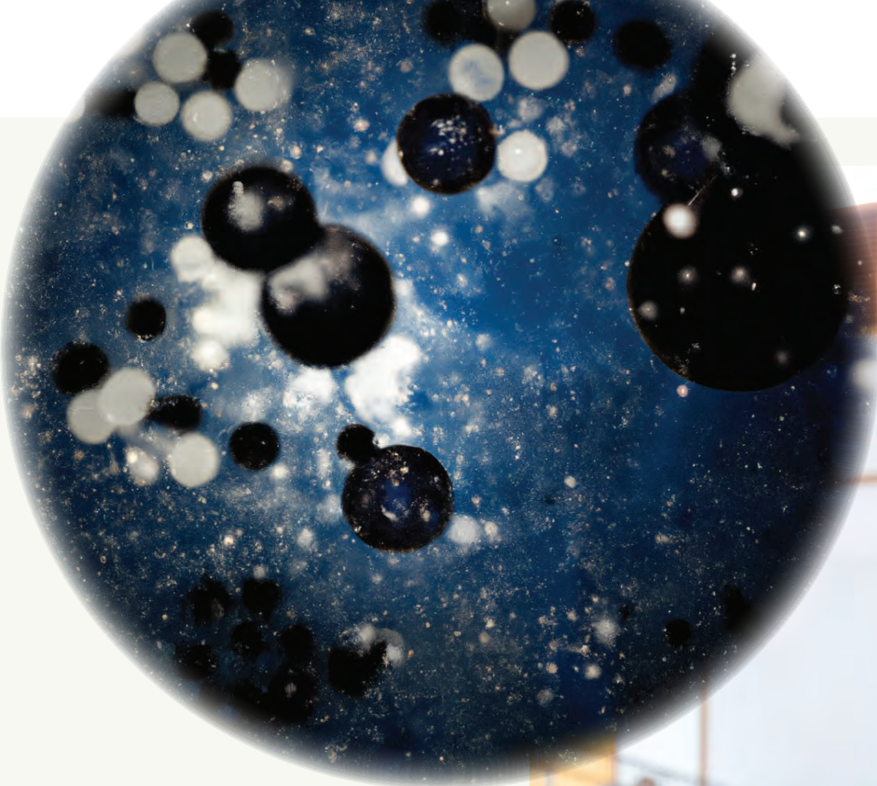
“Understanding how organic complexity can emerge in this strange physical realm is a big goal for this area of science. The chemically complex materials we are learning about could go on to be feedstock for origins of life chemistry in a later stage.”

CONNECTING THE DOTS

Most recently, Bergner was a NASA Sagan Postdoctoral Fellow at the University of Chicago. Rather than centering her research among astrophysicists or chemists, she was based in the geophysical sciences department. Being immersed in a new field, she says, helped her think about astrochemistry in a new way— she integrated data on remnant materials found in our own solar system, like comets, into her research.

“With astrochemistry, you constantly have to bring multiple angles together. The telescope data gives us snapshots of the chemical composition of these environments and the lab experiments give us a mechanistic understanding of how chemical processes might happen,” says Bergner. “But you also need to consider the physical dynamics that are going on.”

With her move to Berkeley, Bergner hopes she’ll be able to pull even more new approaches into her studies on early planet formation. Being back in a chemistry department, she’s looking forward to applying new physical chemistry techniques that can be used to analyze the reactions she carries out.



BRITTANY HOSEA-SMALL

"We are already building an ice lab here, complete with vacuum systems that let us mimic space-like conditions," says Bergner. "I'll be continuing to analyze how volatile molecules behave physically and chemically in these conditions."

Bergner will also be using data from the WEBB, which was launched in December 2021, to enhance her research.

"In the last decade or so, we've mostly relied on radio wavelength data, which gives us access to molecules in the gas phase, but a lot of what I'm interested in is in the ice phase," she says. "WEBB is going to allow us to actually directly measure the composition of ices in these star- and planet-forming regions."

Bergner credits her constant curiosity about the universe with keeping her motivated daily.

"This is just such an intrinsically cutting-edge topic," she says. "Some exciting questions to research going forward include: How do planets form? Where did our water come from here on earth? Can icy bodies deliver organic precursors to new planets? We are just getting started."

HENDRIK UTZAT

Pushing the limits of light

BY SARAH C.P. WILLIAMS

Every second, a typical 60-watt, incandescent light bulb emits about one hundred quintillion photons, the basic units of light. Assistant professor Hendrik Utzat, PhD, who joined the College of Chemistry in July 2022, studies how to generate, manipulate and measure just one of those photons at a time. His research sits at the intersection of nanophotonics with materials science, and optical spectroscopy.

"The overarching thread of my research is the study of the interaction of photons with small-scale structures," says Utzat. "There are many different contexts for this interaction, but the underlying physics and the instruments we use to probe the interactions are the same."

Utzat came to Berkeley from a postdoctoral research fellowship at Stanford University, where he studied optical cavities, which use miniscule mirrors to control the trajectories and behavior of photons.

CREATIVITY MEETS MATHEMATICS

Utzat spent his childhood in Essen, Germany— a small, former coal-and-steel-city that he likes to compare to Pittsburgh. Growing up, he always liked math, and knew he wanted to study something that relied heavily on numbers. As an undergraduate at RWTH Aachen University— a few hours away from Essen on the German border with the Netherlands and Belgium— he found himself deciding between economics and chemistry. He chose chemistry.

"To me, chemistry is the perfect match between being both intuitive and quantitative," says Utzat. "You can use your creativity to come up with ideas about how things work, and then you have to back up those ideas with calculations."

During his time at RWTH Aachen, Utzat worked as an undergraduate research assistant— first studying nanoscience and then spectroscopy. He became fascinated with spectroscopic methods that used light to probe matter, as well as new nanomaterials that interacted with light in unusual ways.

"I learned about the symbiotic feedback loop between materials development and advanced optical characterization," he says. "That idea has driven my research ever since."

ONE PHOTON AT A TIME

After a brief stint at ETH Zurich, in Switzerland, where he got a Master's degree in chemistry, Utzat began his Ph.D. at the Massachusetts Institute of Technology in the lab of Moungi Bawendi.

Utzat became especially interested in tiny, nanoscale semiconductor structures that researchers were designing to emit a single photon at a time. These structures, he says, are like the world's tiniest light bulbs. Like light-emitting diodes (LEDs), they likely have a plethora of applications.

"One of the interesting things about these materials is that if you have a communication line that relies on single photons, there's no way it can be intercepted because you can't split a single photon into two," says Utzat. "But it's also the kind of technology that, if it eventually works, can lead to all kinds of other applications that we can't even imagine right now."

One of the challenges in developing single-photon emitters was that there weren't accurate methods to characterize new materials. So Utzat's graduate research focused on the development of a new, highly accurate spectroscopic technique to resolve miniscule fluctuations in the emission color of individual photons. When this research was coupled with new materials design, it led to Utzat and his colleagues developing the first chemically-made semiconductor nanocrystal with a high optical brilliance— research published in the journal of Science and useful in quantum optics.

MOVING WEST AGAIN

"I like to joke that with each new step of my career, I've successively traveled west," says Utzat.

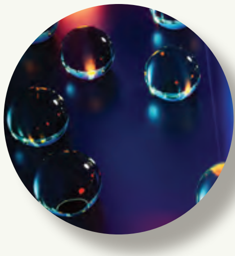
Indeed, after Germany, Switzerland and Boston, he flew west to Stanford University for a post-doctoral fellowship with Jennifer Dionne, one of the leading figures in the field of nanophotonics. At Stanford, Utzat began to study how single-photon emitters could be integrated into larger structures.

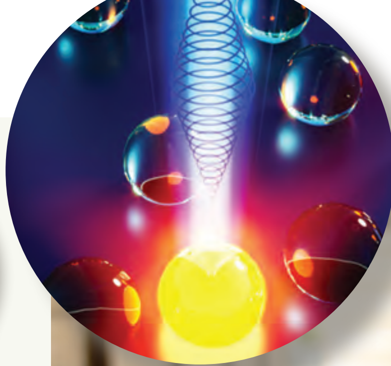
"Normally, light from a single photon emitter is emitted in all directions, like a light bulb," he explains. "But if you put the emitter within an optical cavity, you have a way to control the direction."

Understanding how light interacts with these optical nano-cavities, Utzat says, has implications beyond single photon emitters. Recent studies have suggested, for instance, that materials in optical cavities could be used in high-efficiency solar cells.

DRIVEN BY FUNDAMENTAL QUESTIONS

In his lab at Berkeley, Utzat is still working toward the development of both nanoscale optical materials and optical spectroscopy methods to study those materials. While he is driven by fundamental questions about the behavior of light, his research has implications in other areas including the development of quantum systems that emit single photons. In particular, his lab focuses on how to leverage new detection technologies— and develop new technical tools, measurement techniques, and statistical algorithms— to further this field.





KEEGAN HOUSER

But Utzat is also taking his technology in a new direction. The same spectroscopic techniques and measurement paradigms used to probe single emitters can also be used to study the structures of biological molecules— like individual proteins— in a more sensitive way than existing biological imaging approaches.

“The new single photon detectors we have access to are exceptionally sensitive and have an exceedingly high signal to noise ratio,” says Utzat. “They’re about four orders of magnitude better than conventional single-photon detectors.”

That means scientists can use the detectors to determine exactly how light is bouncing off and interacting with a protein. In turn, that lets them elucidate its precise structure, he proposes. This technology, Utzat says, represents a promising step toward precise, single-protein imaging.

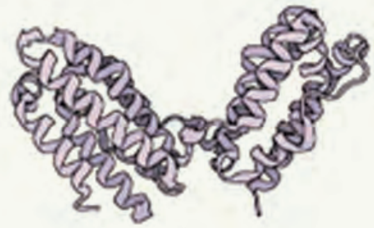
“My work with single-photon emitters and my work with ultra-sensitive biological imaging is driven by this motivation to understand, at a very fundamental level, how light interacts with nanoscale matter and how we can control that interaction through new optical techniques and new materials design,” says Utzat.

Once Utzat’s lab is fully up and running, he looks forward to launching collaborations with Berkeley chemists and biologists to apply his knowledge and approaches to a diverse range of applications— from biology to quantum physics, and beyond.

“One of the reasons I chose to come to Berkeley was that it’s easy to find inspiring, open-minded collaborators across all these disciplines,” says Utzat.

ROBERT SAXTON

Learning the language of the immune system



BY SARAH C.P. WILLIAMS

A decade ago, Dr. Robert Saxton was a Berkeley undergraduate torn between a pre-med path and a newfound love of basic research. Inspired by his experience studying cell division with Michael Rapé and working as an organic chemistry teaching assistant, he chose the academic path. Now, the College is pleased to welcome Saxton back to Berkeley as an assistant professor with a joint appointment in Molecular and Cell Biology and the College of Chemistry. His new lab, which launched in January 2023, will study the immune system's molecular signals that spur inflammation and tissue repair.

"What I want to do is use protein engineering to study and manipulate the molecules that the immune system uses to communicate within itself as well as with the other tissues in the body," says Saxton. "This has consequences for understanding and treating cancer as well and inflammatory and autoimmune diseases."

Saxton returns to Berkeley after graduate school at the Massachusetts Institute of Technology (MIT) and, most recently, a post-doctoral fellowship in the lab of Chris Garcia at Stanford University.

A PATH TO TRANSLATIONAL RESEARCH

Saxton grew up in southern California, always interested in science and drawn to a career in medicine. He joined Rape's lab at Berkeley, initially, to boost his basic science skills and pad his medical school resume. But he quickly grew to love the comradery and the sense of discovery that came from working in a lab. As Rapé gave Saxton increasing independence in the lab—eventually handing him his own research project— Saxton's plans gradually shifted from medical school to graduate school. In 2012, he won a Berkeley Rose Hills Foundation Fellowship to spend the summer pursuing his research, which revolved around a large protein that controls cell division.

At MIT, Saxton was co-mentored by Thomas Schwartz and David Sabatini, studying how cells sense nutrients. The labs used a convergence of structural biology, biochemistry, and cell biology to understand the mTOR pathway, which cells use to control their metabolism and growth in response to external signals.

"It's really important for cells to be able to react to the availability of metabolites and nutrients in their surroundings," says Saxton. "It turns out the mTOR is not only involved in cancer, but also in the way in which caloric restriction can extend the lifespan."

Saxton became particularly interested in one aspect of this pathway: how cells sense amino acids, the building blocks of proteins. At the time he launched his graduate research project, it was known that the mTOR pathway could be dialed up or down by the presence of amino acids, but not which protein or proteins were directly binding to the amino acids to detect them. Over the next few years, Saxton pieced together the details of how the proteins Sestrin and CASTOR bound to the amino acids leucine and arginine, respectively, fulfilling this role. His research was published in the journals *Science* and *Nature* in 2016.

Today, pre-clinical and clinical studies are probing how targeting mTOR pathways could help treat cancer, metabolic disease, and depression. It has validated Saxton's drive to pursue this line of research.

"I've always been particularly interested in translational problems, and particularly to projects where there's a therapeutic end game," says Saxton.

CO-OPTING CYTOKINE COMMUNICATION

Saxton's research also is working to understand cell communication: either how cells talk to each other or how cells interact with their environment. For his post-doctoral fellowship at Stanford, he wanted to stick to this theme, but explore the field of immunology. Saxton began probing immune signaling molecules called cytokines in the lab of Chris Garcia.

"Cytokines are basically the language of the immune system," Saxton explains. "And the immune system is obviously extremely important for nearly all aspects of human health."

Cytokines have as many diverse functions as the immune system itself—triggering and quelling inflammation and spurring tissue regeneration after injury or infection, to name a few. Existing therapies block particular cytokines to shut off inflammation, but few drugs have successfully mimicked the more beneficial effects of the proteins.

With Garcia, Saxton and his colleagues, worked to understand the structural and chemical details of two cytokines, IL-10 and IL-22, in the hopes of creating new versions of the molecules that could be beneficial as treatments for autoimmune disease and chronic inflammation.

BRITTANY HOSEA-SMALL

"We were trying to use this natural mechanism that your body already has for turning off inflammation, but without shutting off your whole immune system and increasing your risk of infection," he says. "We think cytokines can be engineered to turn off inflammation in a more subtle and targeted way."

In a 2021 paper in the journal *Science,* Saxton and Garcia reported that they could successfully design variants of IL-10 with more selective anti-inflammatory properties.

BACK AT BERKELEY

When searching for a place to launch his lab, Saxton put Berkeley at the top of his list. A long-distance runner, he loves the weather and lifestyle of Northern California, and knew from experience how at-home he would feel on the Berkeley faculty.

"The scientific environment here is very collaborative, collegial, and supportive," says Saxton. "I really think that's truer here than lots of other places. The opportunity to work with some of the best students in the country was also a big draw."

In his newly launched lab, Saxton plans to continue looking at how to re-engineer cytokines and other signaling proteins for clinical benefit. In addition to questions about how the molecules turn down inflammation, he also wants to understand how cytokines promote repair and regeneration during an infection or in the context of inflammation.

In cancers, these tissue regeneration pathways are often turned up— they can be part of what drives the growth of tumors. In autoimmune disease, however, the same pathways can be turned down.

"If we have a deeper understanding of how to control these cytokines, we can push them in two different directions, to turn on or off these cellular programs," he adds.

Q&A

KAY XIA: INAUGURAL COLLEGE OF CHEMISTRY DIVERSITY, EQUITY, AND INCLUSION SCHOLAR

Fifth year graduate student Kay Xia (lab of Dean Toste) is the first recipient of the College of Chemistry Diversity, Equity and Inclusion (DEI) Scholar Program. This scholarship covers a year of tuition and includes a stipend for a graduate student to work on a project that's related to DEI in the Department of Chemistry. We were delighted to speak to Kay Xia, the inaugural scholar, about her interests and approach to establishing a course for incoming graduate students on the ethics of scientific discovery.

College of Chemistry: Kay, thank you for talking to us about your project. What interested you about participating in the DEI scholarship program?

Kay Xia: Initially I was interested in looking at the question of whether the research we currently do in our labs might contain some personal biases towards certain groups of people. If we look at the question historically, studies have shown that research can inequitably benefit people who are already in positions of privilege. When there are identified harms resulting from research, the most impact appears to be toward people from communities historically excluded from scientific research.

CoC: What made you decide to develop a course on scientific ethics?

KX: The Chemistry graduate students have been doing an annual graduate student climate survey since 2018 looking at several questions about the student experience at the College. I added a set of questions that asked what factors are important that their research topic addresses.

CoC: What did you learn from the results?

KX: The results were nice to see. The three major traits the survey results showed the students valued included the novelty and originality of their research, the importance to basic science, and increasing personal knowledge or skills. Many students answered that improving social equity was personally important, but they didn't see how chemistry could impact it. Students also responded that various prosocial impacts should be valued more than they currently are.

CoC: How did the climate survey guide your class development?

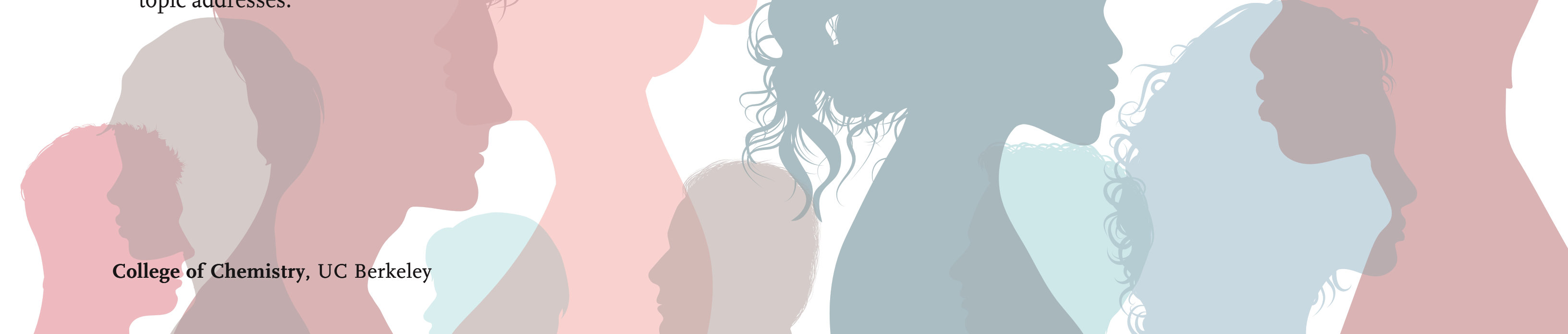
KX: As a result of the 2022 spring survey, we decided to develop a scientific ethics class for the fall semester. It was a required course for first year grad students, but we wanted to keep the workload light because fall semester is a busy time for them. The class was part of their research credit. They met six times throughout the semester as a discussion group with the department chair Matt Francis and Associate Dean for DEI Anne Baranger, to discuss various case studies.

CoC: What did you use for your first case study?

KX: The first case study looked at Berkeley and nuclear chemistry discoveries. The focus was on the initial research of generating plutonium. We also looked at the long-term issues of mining of uranium and the fallout of the pollution from that. It was a good case study to lead with because it helped the students understand that these research issues are complicated and even very basic research can have large impacts. And even for something that a lot of students initially thought was very black and white, for example military research, is not so simple.

CoC: What were the other case studies?

KX: The second case study was on hormonal birth control. Organic chemists Carl Djerassi and Luis Miramontes synthesized the first progestin derivative that ended up becoming the first birth control pill. Some of the fallout we discussed were the questionable practices used in the trials in Puerto Rico by biologist Gregory Pincus and obstetrician John Rock. There were also the impacts to the indigenous population harvesting wild Mexican yams used in the production of the pill.



The third case study was about rare earth elements, which are useful in a number of chemical industries, including clean energy and computer manufacturing. We looked at the mining and sourcing issues including environmental, political, and socioeconomic impacts. We were using that as a way to get the students to think about the life cycle of chemicals.

The fourth case study was on the general topic of legacy chemicals that enter widespread use before it is discovered there are negative impacts. We focused on PVCs because they're manufacturing process is very toxic and hazardous and they are a "forever plastic". At the same time, PVC pipes are the main replacement for lead piping, which is very positive. And when they're used for non-consumable things, they're actually very durable and can be a useful material.

As a positive example, we looked at the Nobel Prize research of alumnus Mario Molina, et al, and their work in atmospheric chemistry, particularly concerning the formation and decomposition of ozone. From a humble start on tests of CFCs, within 14 years the world passed the Montreal Protocol to protect the ozone in the atmosphere. This is a huge success story for chemical research.

CoC: What did you take away personally from this project?

KX: I really appreciated how the department worked with me on this so that in a relatively short turnaround the department Chair Matt Francis and Associate Dean of DEI Anne Baranger were both willing to teach an extra course and make it happen. That sent a strong message that the department cares about this as a subject and that they want the students exposed to this kind of material. I also appreciated how the students responded very positively to the course content and the chance to connect with each other over these discussions.

Personally, the fellowship allowed me to take courses in other departments and to spend time developing this course. "They" always say when you teach, you learn the most. It was really cool for me to get to look closer into these case studies. I think this will influence how I do my own research going forward.

ANNIKA PAGE

Upgrading the NMR lab

BY MARGE D'WYLDE

We are very grateful to Builders of Berkeley members Rubber and Joy Chen of PMP Tech for their $2M gift which includes the purchase of two new Nuclear Magnetic Resonance (NMR) instruments for the NMR Facility at the College of Chemistry (CoC-NMR).

ABOUT RUBBER AND JOY CHEN

Rubber and Joy Chen are incredibly generous friends and partners of the College of Chemistry and Builders of Berkeley. Their company, PMP Tech, is known worldwide for the manufacture of innovative high-tech elastomers and other environmentally friendly rubber products for consumer electronics. In 2020, PMP Tech donated $3.6M to establish the PMP Tech Chancellor's Chair in the Department of Chemistry at UC Berkeley, which is now held by Professor of Chemistry T. Don Tilley. The Chens also pledged $10M last year in support of the Heathcock Hall building fund.

PMP Tech was founded in 1978 by Rubber and Joy Chen in Taiwan. With an extensive international clientele, the company focuses on product lines that include functional elastomers (silicone/rubber); dissimilar material bonding (silicone rubber bonded with metal, plastic, textile, glass, etc.); silicone rubbers with precise dimensions; medical grade products; and other products.

The College will receive a Magritek Spinsolve 80 MHz benchtop NMR spectrometer early in 2023. The second instrument, a fully automated 500 MHz Bruker Avance NEO spectrometer that is equipped with a highly sensitive detector, a cryoprobe, will come later in the year. The addition of these new state-of-the-art instruments will greatly enhance the CoC-NMR's capacity for supporting research and education as part of our mission at the College of Chemistry.

The CoC-NMR is located on the D level of Latimer Hall in a single 2100 square foot laboratory. Their current resources include seven NMR spectrometers which are available for hands-on use to all members of the UC Berkeley and Berkeley Lab communities, including undergraduate and graduate students and postdoctoral and visiting

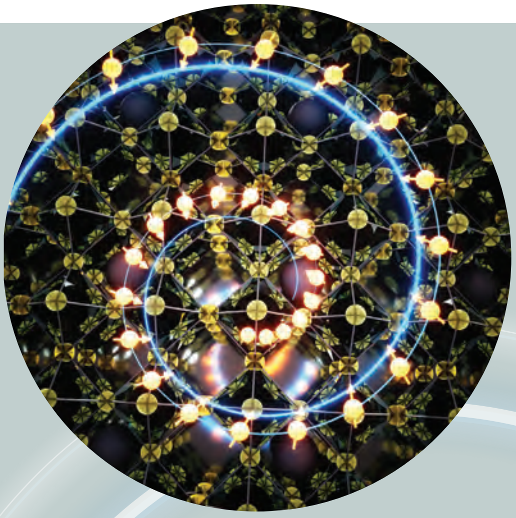
scholars. The CoC-NMR instruments are available for use 24 hours a day year around. During the 2021-22 academic year, the CoC-NMR served more than 500 users who ran over 30,000 hours of NMR analysis. Most NMR users were members of the UC Berkeley community coming from the chemistry, chemical and bioengineering, chem-bio, and environmental and materials science groups. Berkeley Lab researchers and Bay Area companies also regularly access analytical resources available at the facility.

Additionally, the CoC-NMR runs an undergraduate training program for students taking advanced synthetic labs such as Chem 108 and Chem 115 as well as first year graduate students taking Chem 265. Once trained, these students can independently analyze their samples with the CoC-NMR spectrometers. The Magritek Spinsolve instrument will be dedicated to supporting undergraduate research and education in these labs and will play a critical role in professional development for our students.

The facility's director Hasan Celik states, "The NMR Facility is central to the College's mission of training our undergraduate and graduate students and creating the necessary analytical resources to push the boundaries in all areas of chemical research. It's not just one research group benefiting from these shared resources. In the same space, we have researchers specializing in drug design, organic synthetic chemistry, or catalysis, using NMR spectroscopy to support their science and analyze their results. We also have researchers using the same instruments designing the next generation of materials that are going to hopefully help us solve the grand challenges of climate research. We have done a lot of instrument upgrades recently to meet these challenges but this donation from Mr. and Mrs. Chen will allow the facility to leap forward in our research capacity and capabilities."

"NMR spectroscopy is one of the most powerful ways for looking at chemical bonds," Celik continues. "The new technology we are acquiring with the 500 MHz instrument will be much more sensitive than our existing equipment. Currently, certain experiments can take 10, 20, or 30 hours to run. With this new instrument, we can cut down that time by a factor of 10. As a result, we will be able to finish in three hours an experiment that previously took 30 hours. This is a quantum leap forward for the facility both in terms of efficiency and type of research projects we can now run that will push the boundaries of science.

New discoveries in quantum materials



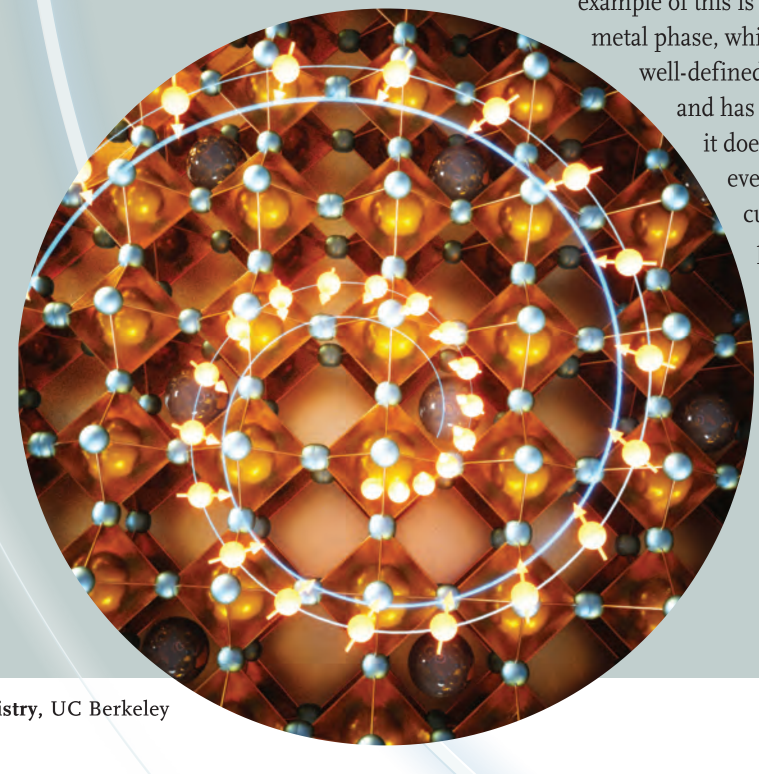
BY MICHAEL ZUERCH
ILLUSTRATIONS: ELLA MARU STUDIO

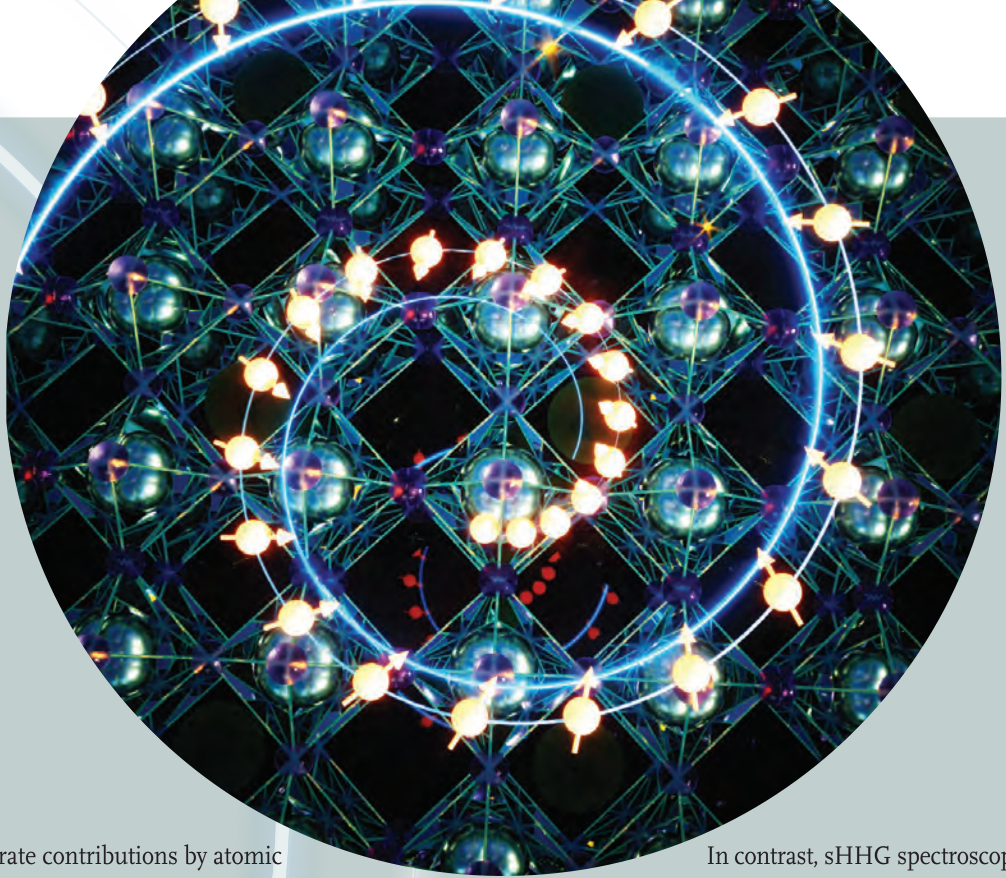
In the last decade, quantum materials have garnered much attention due to their unique properties resulting from interactions between charge, spin, and lattice degrees of freedom at the molecular level in addition to topological effects that can create unique properties at material surfaces. These new materials have the potential to revolutionize fields such as clean energy production, energy storage, quantum computation, and communications.

Understanding the underlying phenomena is critical for the design of future quantum materials and their integration into complex devices. Traditionally, researchers have focused on modifying these materials' properties using static methods such as strain, temperature, applied electric and magnetic fields, chemical composition, or advanced geometric assembly. Now researchers are starting to study time-dependent properties in quantum materials by using light pulses to dynamically engineer material properties with response times down to the femtosecond timescale often referred to as "ultrafast timescale". Such dynamical control is particularly important in applications that require fast switching of a material property such as in memory and computation.

Largely unexplored are such questions as, how tiny energy fluctuations in a system with coupled degrees of freedom can lead to drastic changes of macroscopic properties; how exotic ground or excited states emerge from changes in crystal symmetry or electronic topology; and how quantum materials behave in realistic environments for integration into real-world applications. An example of this is a mysterious phase of matter called strange-metal phase, which exhibits transport phenomena without well-defined quasiparticles. While we know this phase exists and has been observed in many quantum materials, it does not follow known concepts of transport and even a theoretical description is absent. Sparked by curiosity to understand the underlaying physical phenomena, scientists are currently working to describe and measure this phase from a spectroscopic or symmetry point of view.

Ultrafast techniques such as photoemission, scattering, and optical spectroscopies have become powerful tools for studying time-dependent properties in quantum materials. However, conventional time-resolved methods





lack sensitivities for example to separate contributions by atomic elements, buried interfaces, symmetry, and topology on relevant timescales. These shortcomings call for the development of more advanced methods straddling the interface between materials science, physics, and chemistry.

The group of Assistant Professor Michael Zuerch is exploring this interesting new space of non-equilibrium phenomena in quantum materials by the development and application of novel types of spectroscopies in pursuit of unlocking the mysteries of quantum materials. In a recent review published in *Nature Reviews Materials,* three ultrafast spectroscopy methods are discussed, including Attosecond Transient Absorption Spectroscopy (ATAS); Solid-state High Harmonic Generation Spectroscopy (sHHG); and Extreme-ultraviolet Second Harmonic Generation Spectroscopy (XUV-SHG). These techniques have only begun to be applied to the study of quantum materials in the past few years. Zuerch has established the Ultrafast Materials Chemistry Laboratory operated by his group in the basement of Giauque Hall.

ABOUT THESE NEW SPECTROSCOPY TECHNIQUES

ATAS is a technique that creates non-equilibrium conditions in a material using a femtosecond optical pulse and probes them using a time-delayed extreme-ultraviolet attosecond pulse. The extremely short probe pulse allows for studying the fastest carrier interactions within the material, while the use of extreme ultraviolet light allows the resolution of dynamics in a material from the viewports of the different atomic elements.

In contrast, sHHG spectroscopy uses a femtosecond mid-infrared laser pulse to periodically accelerate electrons within a material. The visible light emission from these accelerated electrons encodes information about the energy landscape and interactions between electrons in the material. sHHG provides information about crystal symmetry and dynamic symmetry on ultrafast timescales. Further sHHG is highly relevant for studying quantum materials in operando as all involved wavelengths readily transmit through layers of glass and liquids.

Extreme ultraviolet second-harmonic generation (XUV-SHG) spectroscopy uses two photons in the extreme ultraviolet to emit a photon at twice the frequency, allowing the study of functional properties resulting from symmetry breaking. It's useful for studying dynamics at buried interfaces and surfaces with femtosecond resolution, which is highly relevant in layered quantum materials. XUV-SHG can also be used to study ion dynamics at interfaces, which is valuable for developing new solid-state electrolyte materials for batteries.

Quantum materials remain one of the most active and exciting areas of research in materials science, physics, and chemistry. Emerging ultrafast techniques we are currently actively developing at the College of Chemistry offer unique capabilities to address some of the most challenging problems in this field and open up exciting possibilities that could lead to new breakthroughs in materials chemistry and technology.

Catalyst

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"Our goal is to construct a building that will carry us into the next generation of scientific discoveries and create an equitable and inclusive level playing field for students from every background"

—**RICHMOND SARPONG,** Executive Associate Dean, College of Chemistry

Heathcock Hall will be a place of groundbreaking research possibilities and an important educational portal for generations of chemistry and chemical engineering students. Help the College reach our goal of commencing construction in 2023. Consider a naming opportunity to sponsor a floor or a lab.

Contact Mindy Rex by email at **rex@berkeley.edu** or call **(510) 642-9506** to discuss opportunities for naming donations.

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