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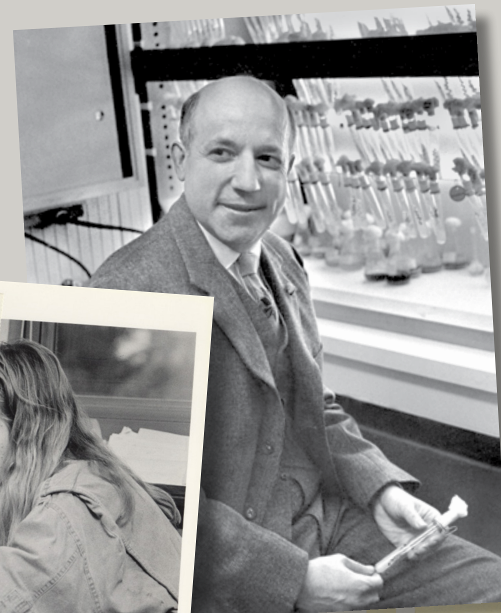
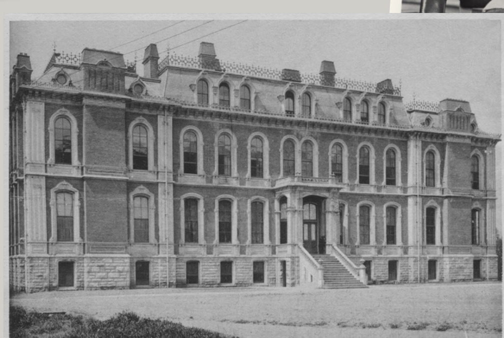
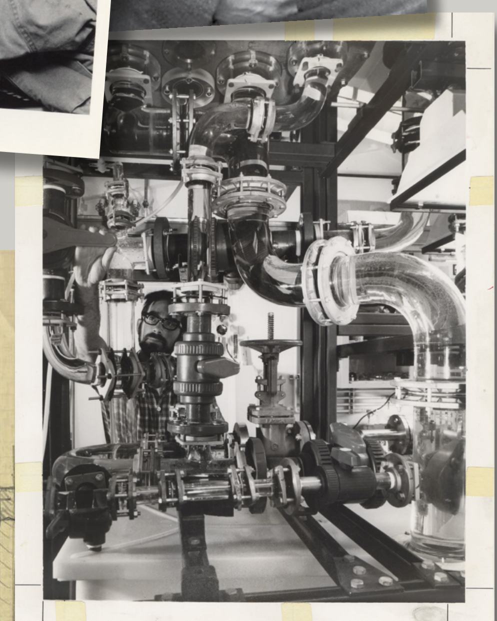
Catalyst

Spring/Summer 2018 Volume 13 • Issue 1

COLLEGE OF CHEMISTRY • UNIVERSITY OF CALIFORNIA, BERKELEY

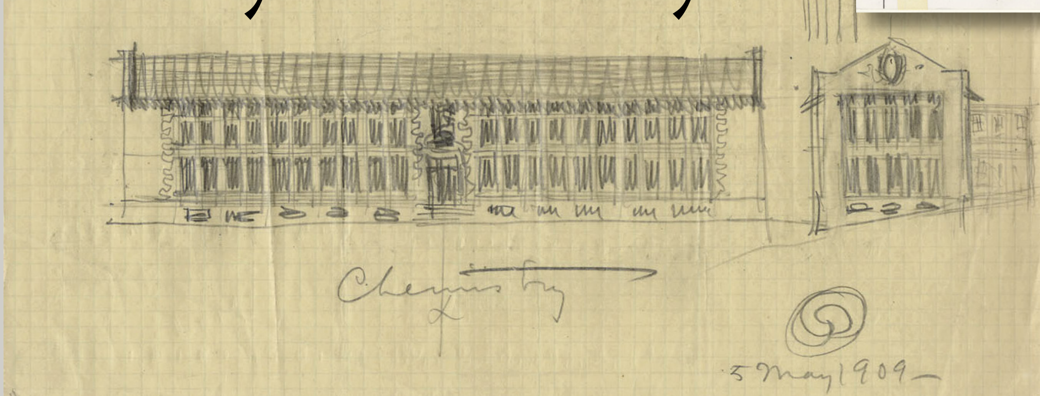






BERKELEY 150 1868 ★ 2018

Celebrating 150 Years *of* Chemistry at Berkeley



Catalyst

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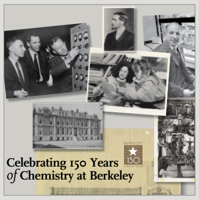

ON THE COVER

Scenes from 150 years of history: (top left) Oppenheimer, Seaborg and Lawrence in the lab, Gilbert N. Lewis, Melvin Calvin, Judith Klinman, chemical engineering lab c. 1960, South Hall, and Gilman Hall. See page 25 for details.

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chemistry.berkeley.edu/catalyst

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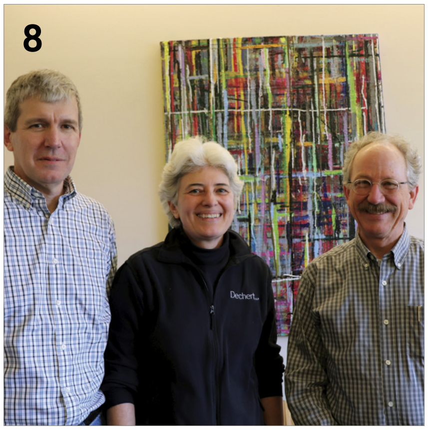

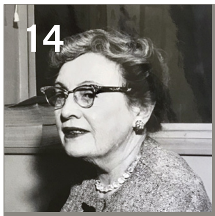

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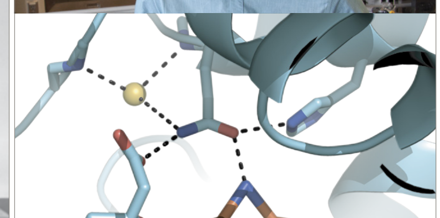
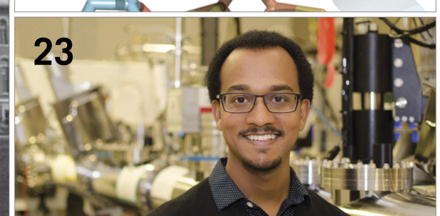
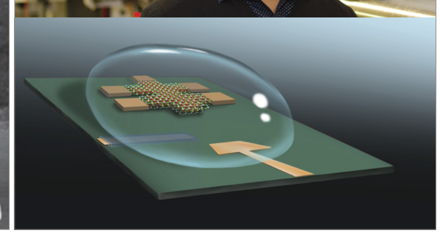






Mining, Chemistry, and Library buildings c. 1897, Oliver Family photo collection.
COURTESY BANCROFT LIBRARY, UC BERKELEY


TOLMAN HALL

Reading the signs of a future unseen

This year we are celebrating 150 years of chemistry at Cal. Many of you may be wondering how that can be, given that the College of Chemistry wasn't established until 1872 (by an act of the state legislature, no less). However, we checked the University of California Historical Archive and found that one of the ten initial members of the faculty of the University, Robert A. Fisher, was professor of chemistry, mining and metallurgy in the newly formed College of Agriculture. Fisher taught the first chemistry course on the temporary campus in Oakland and traveled to Europe to buy the first lab instruments and reference books. Thus, there was a chemistry presence at Cal from the University's founding. By the turn of the century the number of degrees awarded each year had increased from around three to 15. Last year we awarded a total of 382.

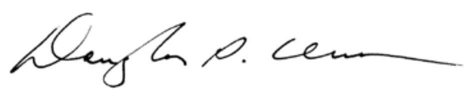
Having such a distinguished history and record of excellence for 150 years puts us ahead of some impressive American institutions. Dow Chemical Company was founded in 1897, and the Hershey Company a little earlier in 1894. Comparatively, the Ford Motor Company and New York Yankees were relative newcomers; both got their start in 1903. The College of Chemistry predates them all (and through its faculty, students, and alumni has spawned a number of successful companies of its own), and arguably, is unmatched in its reputation of sustained leadership at, or near the top, of its field throughout the world. Our record of achievement includes multiple Nobel Prizes and discoveries that have changed the course of humankind, all while educating generations of students who themselves have gone on to make their marks worldwide. It is an inspiring history, but past performance is no guarantee of future success.

Much has changed in the last 150 years. Advances in the chemical sciences, and their impact on our daily lives, have been nothing short of phenomenal. Many of those life-changing advances can be traced to research that was carried out in the College of Chemistry. A timeline of groundbreaking discoveries and notable accolades attributed to the College can be found on our website at chemistry.berkeley.edu/timeline.

Even more will change in the next 150 years, with dissemination (if not synthesis) of new knowledge becoming nearly instantaneous and the impact of technology expanding on a number of fronts, many of which we cannot foresee. What will not change are our core values and mission of advancing society through education and research, which have enabled us to maintain our excellence for so long. We have fulfilled this mission, year in and year out, since our start. Education reflects our heart and soul, while research embodies our spirit.

Predicting the future can indeed be difficult, but not always. For example, chemicals, chocolate, transportation, and baseball will endure. And certain trends will no doubt continue: disciplinary lines will blur as science and engineering merge at the molecular level; amazing new products will result from greater understanding of how to manipulate the properties of matter; and scientific exploits at the atomic scale will grow in quantum leaps and bounds. Other trends, including some of the most exciting, have yet to develop and cannot be predicted. However, through it all, the College of Chemistry will continue to educate, mentor, diversify, and expand the frontiers of human knowledge with passion and commitment, striving to maintain if not exceed the standard of excellence it has set for well over a century. Future generations of students and alumni will help see to that. I know we can count on them for their support. Just as we can count on all of you.

So, let us embrace the future. It will be here sooner than we think, ready for all to recognize.



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

"Prediction is difficult, especially when dealing with the future".
—DANISH PROVERB

Dean Douglas Clark stands in front of Tolman Hall, which will be demolished this year to make way for the new Berkeley Science and Engineering Hub.

NEW & NOTABLE

RESEARCH • VIEWS
DISCOVERIES • AWARDS

A career in catalysis: Alexis T. Bell

On the occasion of the Dow Professor of Sustainable Chemistry Alexis T. Bell's fiftieth year at Berkeley, a group of Bell's former graduate students and postdocs have created a high-level career summary of his substantial research.

Having inspired around 700 papers to date and 180 students and postdoctoral associates, Bell's career spans a broad and important set of research problems. The writers' aim was to share a representative set of vignettes as a window into his approaches and patterns and to illustrate his enduring impact on the field. These are arranged roughly chronologically, addressing chemical vapor deposition, characterization of catalysts and catalytic processes, CO hydrogenation on supported metals, zeolite synthesis and design, partial oxidation on metal oxides, and quantum mechanical and statistical mechanical computation.

The paper was recently published in *ACS Catalyst* and is entitled: "A Career in Catalysis: Alexis T. Bell".

Changes in the College's Advisory Board

The Advisory Board fills a tremendously important function for the College both as mentors and as liaisons into the business world. We are grateful to all of these members for their service and support.

....

The following alumni, and friends of the College, joined the Advisory Board in 2018:

SHIH HUNG CHAN, Ph.D., Distinguished Professor Emeritus, Fuel Cell Center/ Department of Mechanical Engineering, Yuan Ze University

RUBBER CHEN, B.S., CEO, Pioneer Material Precision Tech (PMP Tech)

MARGARET CHU-MOYER, B.S., Executive Director, Amgen Inc.

ZHIPING (PHILLIP) CUI, MBA, Vice President and General Manager of VC Investment Department, Shanghai Fosun Pharmaceutical (Group) Co., Ltd

TED HOU, Ph.D., CEO, NEEM Scientific; General Partner, Berkeley Catalyst Fund

CYNTHIA MURPHY-ORTEGA, B.S., Manager, University Partnerships & Association Relations, Chevron Corporation

ELLIE YI-LI YIEH, B.S., Vice President & General Manager, Applied Materials, Inc.

....

We also wish to extend our sincere thanks to the following Advisory Board members who stepped down:

JAMES FOSTER, B.S., EVP Product Supply, Enterprise Performance & IT at The Clorox Company

JAMES TRAINHAM, Ph.D., CTO of JDC Phosphate.

....

TERRY ROSEN, Ph.D., CEO, Arcus Biosciences, has moved into a new adviser role as the first *Special Adviser to the Dean.*

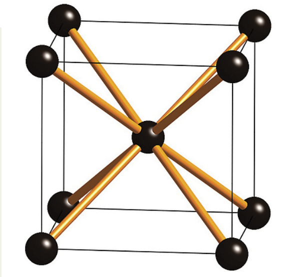
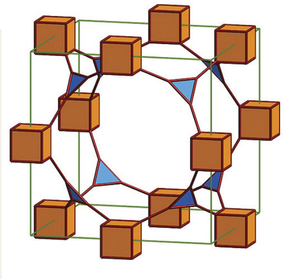
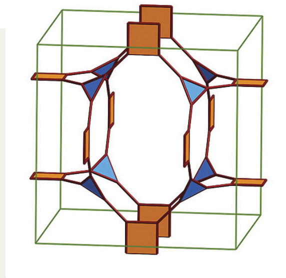
MORE INFORMATION IS AVAILABLE ABOUT THE ADVISORY BOARD AT: chemistry.berkeley.edu/advisory-board

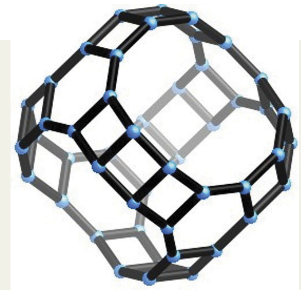
Changes in College leadership

Dean Douglas Clark recently announced changes in College leadership. Professor **MATT FRANCIS** will serve as Department Chair in Chemistry effective July 1, 2018. Francis has most recently served as the College of Chemistry Executive Associate Dean, functioning as the chief operations officer, and previously as vice-chair of the Synthetic Graduate Program in the Chemistry Department.

DAVE WEMMER will be stepping down after four years of exemplary service as Chemistry Chair. Under Wemmer's steady leadership, the Department has hired exceptional assistant professors, successfully retained faculty, and worked collaboratively with colleagues and administrators to maintain the department's reputation as the top graduate program in the country, if not the world.

Clark also announced that Chemistry Professor **RICHMOND SARPONG** will step into the role of executive associate dean in the College of Chemistry, effective July 1, 2018. Sarpong currently serves as vice-chair of the Synthetic Graduate Program in the Chemistry Department. As executive associate dean, he will oversee the internal operations and infrastructure of the College and will also serve as director of Research Facilities.



Professor Omar Yaghi awarded the 2018 Wolf Prize

The Wolf Prize in Chemistry has been awarded to the James and Neeltje Tretter Professor of Chemistry, Omar M. Yaghi, for "pioneering reticular chemistry via metal-organic frameworks (MOFs) and covalent organic frameworks (COFs)." Omar shares this year's prize with Makoto Fujita from the University of Tokyo.

Yaghi's research into MOFs, COFs, and ZIFs (zeolitic imidazolate frameworks) is the seed that has grown into a new chemistry now sweeping the world, with hundreds of laboratories pursuing fresh applications for these porous materials. The new Wolf laureate has counted to date more than 70,000 varieties of developed crystalline materials based on reticular chemistry, which he defines as stitching molecules together by strong bonds into open frameworks.

Yaghi will join other laureates, including Sir Paul McCartney at an induction ceremony later this year in Israel.

Assistant Professor Markita Landry receives 2018 Alfred P. Sloan Research Fellowship

The Alfred P. Sloan Foundation has awarded Markita Landry, assistant professor of Chemical and Biomolecular Engineering, a 2018 Sloan Research Fellowship for her work in neuroscience. Landry is one of a select group of U.S. and Canadian researchers honored for their early-career achievements marking them as the next generation of scientific leaders.

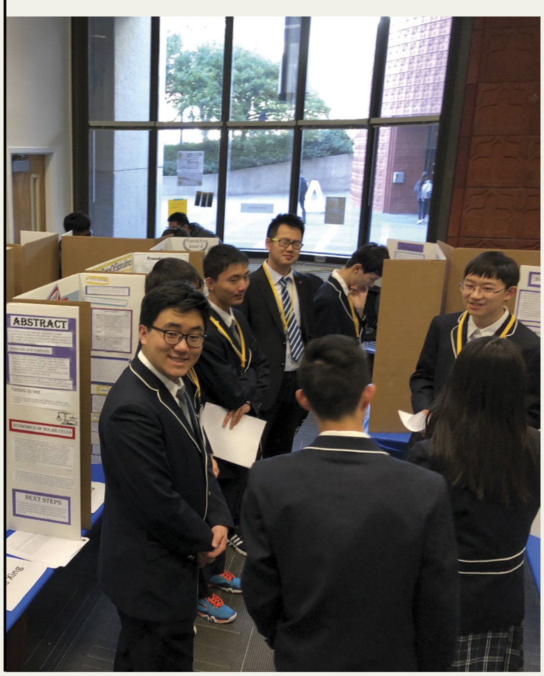
Landry and her team are involved in groundbreaking research to develop a new nanosensor technology and near-infrared imaging platform that will enable non-invasive imaging of neurotransmitter activity in the living brain. The research is specifically looking at the problem of how to test psychiatric and neurological drug efficacy in the brain with infrared light. Optical detection of neurotransmitters in the brain of an awake animal will enable direct study of the fundamental underlying mechanisms of behavioral disorders, which can accurately validate the neural action of a psychiatric drug.

GOLD program takes off

The first cohort of high school students in the College's Guiding Outstanding Learners to Discover© (GOLD) program recently successfully completed their 9-month program. Twenty students from Nanjing #1 High School in Nanjing, China arrived in February to meet with their graduate mentors and finish their projects.

For eight months, graduate students from our Chemistry and CBE departments had been working remotely with these high school students on such varied projects as air pollution, building a better battery and solar cells. Once on site at the College, the students spent time in their mentors' labs and completed the write-ups of their experiments, to be displayed and judged at a poster session. This was a novel approach to learning the scientific method for these students, as there is currently no academic culture of high school science fairs in China. 5

The students presented their final projects in Bixby North. The first-place winner, Tommy Xu, received an engraved trophy for his project, "Improvements in Broadleaf Tea Products." All of the students received completion-of-program certificates from Dean Clark.



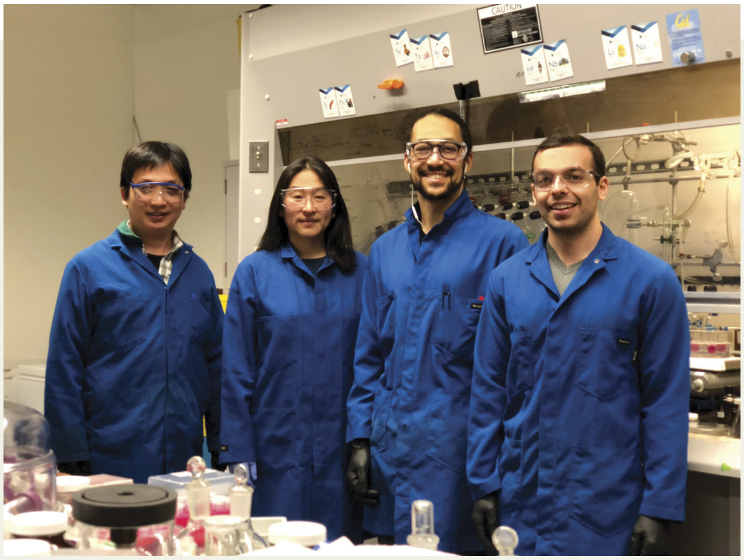
Dean Douglas S. Clark reappointed for second term

Douglas S. Clark has been reappointed as dean of the College of Chemistry for a second five-year term, according to Executive Vice Chancellor and Provost (EVCP) of UC Berkeley, Paul Alivisatos.

Since Clark began serving as dean in July 2013, he has skillfully addressed the College of Chemistry's top priorities including overseeing the hiring of ten faculty and the retention of six others in the face of fierce competition. Under his leadership, the College has successfully met some of its most pressing infrastructure needs. He is also currently working in collaboration with the deans of the Colleges of Natural Resources and Engineering to plan and raise funds for a new joint research building — the Berkeley Science & Engineering Hub.

Noted EVCP Alivisatos, "Beyond (his) achievements, I would like to commend Doug on his inclusive, approachable, and respectful leadership style, which has encouraged successful partnerships within the College of Chemistry and ultimately enabled the College to maintain and improve its top-ranked programs."

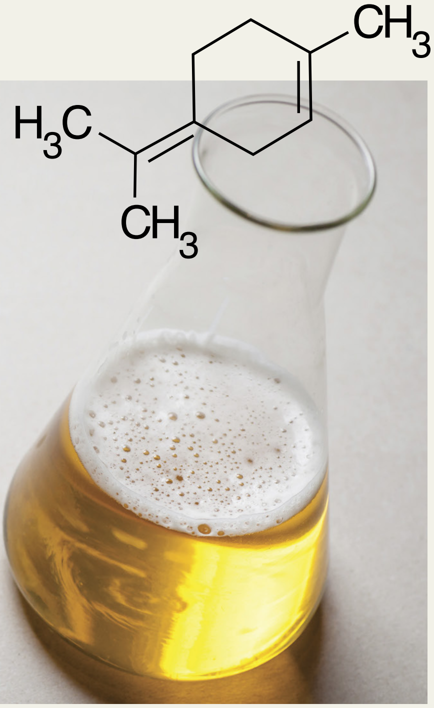
Clark also continues to oversee his research lab. Current projects and collaborations include enzyme engineering for new reactions and improved synthesis, the use of metabolic biochips for high-throughput catalysis and bioactivity screening, protein design and assembly for advanced biomaterials, and biological engineering for support of a mission to Mars.



Research team headed by Professor Ting Xu creates protein mat that can soak up pollution

In a breakthrough that could lead to a new class of materials with functions found only in living systems, a research team from the lab of Ting Xu, professor of chemistry and materials science and engineering, has figured out a way to keep certain proteins active outside of the cell. The researchers used this technology to create mats that can soak up and trap chemical pollution.

Despite years of effort to stabilize proteins outside of their native environments, scientists have made limited progress in combining proteins with synthetic components like fibers without compromising protein activity. The new study shows a path toward exploiting the power of proteins outside of the cell by demonstrating a unique way to keep proteins active in synthetic environments. The materials presented in the study could enable on-demand biochemical reactions, such as in war zones or contaminated sites, where they were once not feasible.



Brewing hoppy beer without the hops

Hoppy beer is all the rage among craft brewers and beer lovers, and now a group of UC Berkeley researchers led by Charles Denby and Rachel Li have come up with a way to create these unique flavors and aromas without using hops.

The researchers created strains of brewer's yeast that not only ferment the beer but also provide two of the prominent flavor notes provided by hops. The engineered yeast strains were altered using the CRISPR-Cas9 gene-editing tool. They inserted four new genes plus the promoters that regulate the genes into industrial brewer's yeast.

Denby initially came to UC Berkeley to work on sustainable transportation fuels with Professor Jay Keasling, a pioneer in the field of synthetic biology. He started home brewing out of curiosity with a group of friends. "I was interested in (the) fermentation process. I found out that the molecules that give hops their hoppy flavor are terpene molecules, and it wouldn't be too big of a stretch to think we could develop strains that make terpenes at the same concentrations that you get when you make beer and add hops to them."

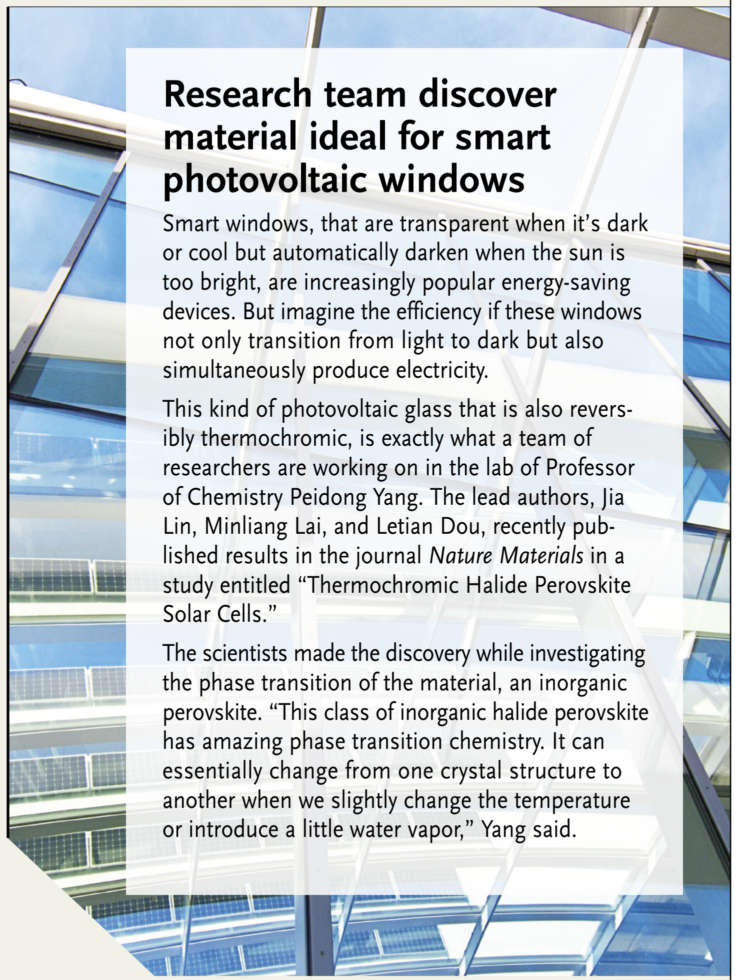
"The final hook was that a hoppy strain of yeast would make the brewing process more sustainable than using agriculturally produced hops, which is a very natural resource intensive product," he said.

Professor Jennifer Doudna honored with National Academy of Sciences Award

Jennifer Doudna, professor of biochemistry, biophysics, structural biology and chemistry, has received the 2018 National Academy of Sciences Award in Chemical Sciences for her pioneering discoveries on RNA folding and for the invention, with Emmanuelle Charpentier, of the CRISPR-Cas9 gene-editing technology.

Following her discoveries on how RNA can fold to function in complex ways, Doudna, along with Charpentier, invented the technology for efficient site-specific genome engineering using the CRISPR-Cas9 nucleases for genome editing — a breakthrough technology which has had an immediate and wide impact on all areas of both basic and applied life sciences.

Doudna was honored in a ceremony in April during the National Academy of Sciences' 155th annual meeting.



Research team discover material ideal for smart photovoltaic windows

Smart windows, that are transparent when it's dark or cool but automatically darken when the sun is too bright, are increasingly popular energy-saving devices. But imagine the efficiency if these windows not only transition from light to dark but also simultaneously produce electricity.

This kind of photovoltaic glass that is also reversibly thermochromic, is exactly what a team of researchers are working on in the lab of Professor of Chemistry Peidong Yang. The lead authors, Jia Lin, Minliang Lai, and Letian Dou, recently published results in the journal *Nature Materials* in a study entitled "Thermochromic Halide Perovskite Solar Cells."

The scientists made the discovery while investigating the phase transition of the material, an inorganic perovskite. "This class of inorganic halide perovskite has amazing phase transition chemistry. It can essentially change from one crystal structure to another when we slightly change the temperature or introduce a little water vapor," Yang said.

Professor John Prausnitz celebrates 90th birthday

As part of the events of the New Vistas for Molecular Thermodynamics symposium held at the College of Chemistry in January, Professor of the Graduate School John Prausnitz was celebrated at the symposium's banquet. The occasion was his 90th birthday. His birthday card, proportionate in size to the birthday, included photographs of the symposium speakers and their signatures.

Prausnitz's former Ph.D. student, Jianzhong Wu, a chemical engineering professor at UC Riverside, organized the symposium. John O'Connell, another of his former Ph.D. students and a professor emeritus and former chair of the chemical engineering department at the University of Virginia, was responsible for the birthday card.

The number of investigators in molecular thermodynamics, especially in computation and modeling, has increased in recent years. The symposium explored how closer collaborations among cross-experimentation of thermodynamic problems can help define new frontiers in molecular thermodynamics, challenging the current thinking of engineering research.

Berkeley Catalyst Fund

We are pleased to report that the general partners of the Berkeley Catalyst Fund have closed Fund I at ~$25M in February of this year. The Fund has been making investments, and is working closely to foster the vibrant startup ecosystem around UC Berkeley, Lawrence Berkeley National Laboratory, UC San Francisco, associated incubators and accelerators, and with alumni throughout the San Francisco Bay Area. The sector focus of the fund is biopharma, agriculture, medical devices, clean air, clean water, energy storage, and sensors. The stage is primarily Seed and Series A.

For more information visit: chemistry.berkeley.edu/berkeley-catalyst-philanthropic-fund

ANN & JOE PEASE

Giving back to the students

Ann and Joe Pease feel they had an outstanding educational experience at the College of Chemistry, both as graduate students and in the wonderful friendships they developed while they were here. They began their Ph.D. research in the mid 1980s under a "new" faculty member, David E. Wemmer. Wemmer had joined the College in 1985, coming from an appointment as assistant professor of chemistry at the University of Washington. Today he is chair of the Department of Chemistry and the Joel Hildebrand Distinguished Professor.

Joe Pease (Ph.D. Chem, 1989) joined Wemmer's lab as one of the first three graduate students in the lab's inaugural year, 1985. Joe's work focused on studies of peptides using NMR, particularly on the study of neurotoxins from honeybees and sea anemones. The ensuing structural insights led to the idea of using disulfide cross-linked frameworks as molecular scaffolds to display structures such as exposed alpha helices.

Joe currently leads the Analytical Chemistry and Purification unit in Small Molecule Discovery Chemistry at Genentech. After graduating from Berkeley, he joined Syntex Corp. as a research scientist. Roche Pharmaceuticals acquired Syntex in 1994. Joe stayed with Roche until their Bay Area facilities closed in 2010. He joined Genentech in 2011. He is a recognized expert in analytical chemistry, nuclear magnetic resonance, and research information systems, especially in developing systems to improve and streamline drug discovery workflows.

Ann Pease (née Caviani) (Ph.D. Chem, 1990) started in 1986 as part of Wemmer's second graduate student cohort. Her research focused on the three-dimensional fold of a self-cleaved RNA hammerhead domain, one of the earliest examples of a catalytic RNA. She also applied NMR spectroscopy, focusing particularly on the low-field region of the spectrum, to identify base pairs in both helical segments and among conserved residues at the three-way junction that was predicted to exist. The work provided the first glimpses of how the RNA sequence stabilized a fold that induced the self-cleavage reaction.

After Ann graduated, she spent several years in research at Affymetrix. The company developed and manufactured DNA microarrays. At the time, only 3% of the company's researchers were women. Her experience made her decide to go on and earn a J.D. from Stanford University Law School in 1995. She is now retired from the law firm of Dechert, LLP where she became a partner in 2005. Ann specialized in intellectual property law and chaired the firm's patent practice. A registered patent attorney, she counseled clients in the biotechnology, pharmaceutical and medical device industries on intellectual property strategy.

Ann and Joe met in the lab — Ann says that it took Joe over a year to get up the nerve to ask her out. Their first date was a movie. They went "undercover," as it was frowned on at that time to date your lab partner. They were sitting in a relatively empty, dark theater when someone sat down right behind them and leaned in between their seats. "Shouldn't the two of you be in the lab right now?" Wemmer asked. He so startled Ann that she reflexively turned around and hit him in his side. Ann and Joe were married in 1989.

Wemmer's lab at the time was located in the "Roundhouse" (aka the Calvin Lab), named for Nobel Laureate Melvin Calvin. Calvin was an emeritus chemistry professor by then but was still active in the lab, sitting in on weekly research meetings. When the Loma Prieta earthquake rocked the Bay Area in 1989, Ann was doing lab research. The building started to shake

Far Left: Ann and Joe in 1989 on the chemistry plaza at a graduation celebration.

Left: Joe and Ann in 2018 in the office of David Wemmer.

violently, but she was working with radioactive phosphorus-32, and had to cap her gels before she could run and stand under a doorway.

Ann and Joe have been long-time dedicated donors to the College, but in 2011 they started giving back in a big way. Joe was working at Roche Pharmaceuticals when it acquired Genentech. Joe explains, "When Roche turned over the buildings to Genentech, this included about $20 to $30 million in top-end lab equipment. One of the first things Genentech did was to remodel the labs. I started making calls and am happy to say that some much-needed equipment wound up going to the College and some of the faculty." According to Alex Shtromberg, assistant dean of engineering and facilities, the College received a number of fume hoods and lab cabinets. The hoods were installed in several teaching labs on the second floor of Latimer Hall while the cabinets were distributed to various faculty labs.

That same year, Joe and Ann also established the *Graduate Student Life Enrichment Fund*. They had learned that significant decreases in state funding over the previous decade had left continued financial support of graduate-student networking and professional development activities at the College in doubt. They decided to start the fund to ensure that these activities would always be given the priority they deserved. The *Graduate Student Life Enrichment Fund* is a matching endowment created to support activities that encourage "the social interaction and information collaborations of graduate students in the Department of Chemistry." One of the ongoing funded items is the graduate chemistry students' Friday afternoon ChemKeg on the plaza.

Ann explains, "Thirty years ago, we had the privilege of being graduate students in the Department of Chemistry at UC Berkeley. One experience we valued was sharing food and drink with fellow students and faculty on Friday afternoons on the chemistry plaza. We connected with old friends, made new ones, and discussed mutual research endeavors."

The Friday afternoon event remains very popular. Current chemistry grad students echo Joe and Ann's experience. "This fund makes it possible for students in different labs and fields to interact. I've made so many friends through these events!" remarked Chrissy Stachl (Ph.D. Chem, 2020). Tyler Hurburt (Ph.D. Chem, 2018) agrees, "Events hosted by this fund encourage students to get out of their labs and interact with others across the department. Without it the department would not be as connected."

Ann and Joe's donations to the College have had a significant impact on the educational experience of our students. As state funding continues to be reduced every year, the College must look to other avenues to support building improvements and quality-of-life events for our students. Joe's facilitation of Roche Pharmaceuticals' donation of lab equipment to the College was a real boon for both the College and faculty. And all you need to do is walk out on the plaza any Friday evening to see their *Graduate Student Life Enrichment Fund* hard at work.

Ann and Joe were recently back on campus to visit with David Wemmer. Ann enthused, "I really enjoy being back on campus. It brings back so many wonderful memories of our time here. I hope that the College's current graduate students will come back someday and feel they had the same kind of experience that we did."

THE BEGINNING OF A WORLD CLASS RESEARCH INSTITUTION

Celebrating 150 Years of Chemistry at Berkeley

BY MARGE D'WYLDE

Robert A. Fisher

Ezra S. Carr

Willard B. Rising

Celebrating 150 years of history is a monumental task: doubly so when it is UC Berkeley's prestigious College of Chemistry. The College has a rich academic and scientific history. When the University of California was founded, the first set of Regents deemed chemistry so important that one of the first ten faculty hired in 1868 was the chemist Robert A. Fisher as the professor of chemistry, mining and metallurgy. His position was in the College of Agriculture because an official College of Chemistry was not organized until 1872.

One of the many challenges Fisher faced was the complete lack of chemical lab equipment available for purchase on the west coast. As a result, Fisher was sent to Europe with the sizeable sum of $9,500 ($275,000 today) to buy the University's first lab equipment and reference books. He taught the University's first chemistry class in the temporary downtown Oakland campus at night with chemical demonstrations. He left the University abruptly in 1870 when the Board of Regents cancelled his faculty position for unexplained reasons.

Fisher was followed by Ezra S. Carr who was hired in 1869 as the professor of agriculture, chemistry, agriculture and applied chemistry, and horticulture. Carr also taught at the downtown Oakland campus with his class open to the public. One of his first students was a very young Edmond O'Neill, who later served as dean of the College from 1901 to 1912. Years later, O'Neill recalled attending Carr's lectures as a boy. "Although it was fifty years ago, I remember the lectures and experiments as though they occurred yesterday. It fired my imagination and gave me my first insight into the charm and interest of science." Carr was a popular lecturer but was politically active, trying to sway University policy at the state level. Because of his political activities, he was removed by the Regents from his position in 1873.

The College of Chemistry, officially chartered in 1872 by the California state legislature, is one hundred and forty-six years old in this year of UC Berkeley's sesquicentennial. Willard B. Rising was hired in 1871 and arrived on campus in 1872 as the first official professor of chemistry in the College. Rising had received his Ph.D. under Robert Bunsen at the University of Heidelberg. As with most chemists of the era, Rising's principal expertise was the chemical analysis of minerals, drugs, agricultural products, and water. In 1885, he took a second position as Analyst for the California State Board of Health to test and certify water supplies statewide. He often worked free of charge to help communities improve their water primarily because the state could not afford to pay him. Rising was the de facto dean of the College until he was officially appointed the first dean in 1896.

Chemistry was first housed in South Hall, the oldest building on campus, designed by the Architect David Farquharson. Farquharson was a well-established architect in the Bay Area at the time and designed many of the original campus buildings. South Hall is the only original building remaining from that period. When it was first opened, the building housed the chemistry and physics departments along with the first campus library. Rising's office, and the College's first set of labs were located in South Hall. The interior furnishings were made from California laurel, the desks black walnut and the hoods were plate glass. The building incorporated stained-glass windows into its design.

According to O'Neill, in a 1918 *Journal of Industrial Engineering Chemistry* article, "When completed, the laboratory was physically superior to any in America and was probably unexcelled by any in the world." He went on, "With the smallness of the classes and the lack of distracting avocations and activities, now unhappily so prevalent, we could devote ourselves to study and reflection...the small college in the midst of uninhabited fields of Berkeley had a charm that can never come again."

South Hall c. 1900

COURTESY OF THE BERKELEY PUBLIC LIBRARY

In 1891, the first dedicated chemistry building was erected. It was designed by the architect Clinton Day, at a cost of $83,500 ($2 million today) was made of 43,180 bricks, and was paid for by University funds. The building contained a lecture hall, numerous laboratories for instruction and research, and faculty offices. It eventually came to be known as the "Old Chemistry Building." The building was demolished in 1963 to make way for Hildebrand Hall. However, its original cupola was preserved and can be seen in the plaza of the College's complex today.

Some of the first graduates of the College became its next faculty. John M. Stillman was the first Ph.D. graduate in 1885. He did his undergraduate work at Berkeley, graduating in 1874, and went to Germany for his graduate training. He returned to lecture at Berkeley from 1876 to 1882 and then went on to work as the Chief Chemist and Superintendent for the Boston and American Sugar Refining Company. He did not write a formal dissertation to receive his Ph.D. His degree was awarded for his "exemplary record as a student and for his publication while a university faculty member of nine papers on the composition of certain resins and the ethereal oil of the California bay tree." Stillman was the first chemistry faculty hired at the inception of Stanford University in 1891. In addition to his teaching and scholarship there, Stillman took an active part in department and university administration, including time as Stanford's Vice President and Acting President. He was executive head of the department from 1904 to 1919.

Edmond O'Neill received his B.S. at Berkeley specializing in chemistry and agriculture. Upon his graduation in 1879, he was appointed instructor in analytical chemistry. Except for the period from 1884 - 1887, when he was a graduate student in Europe, O'Neill spent the rest of his professional life at Berkeley. He taught everything from analytical to physiological chemistry (biochemistry). Physiological chemistry was his main interest and he studied fatty acids of the seeds of the California bay laurel and the terpenes of Monterey cypress. Similar to Rising, he was involved in solving water quality problems around the state. He was dean of the College from 1901 until 1912. Gilbert N. Lewis arrived at Berkeley and became dean in 1912. O'Neill took the position back temporarily during WWI as Lewis was involved in the war effort in France and Washington. O'Neill was a good judge of character and was largely responsible, along with Rising, for hiring Frederick Cottrell and Gilbert N. Lewis to the College faculty.

John M. Stillman

Edmond O'Neil

O'Neill was also associated with student life on campus. He was a member of all the student honor societies, chairman of the Faculty Committee on Athletics, and helped to organize the Alumni Association. He was one of the founders of the Faculty Club and served as its president for ten years. In addition, he was responsible for the formation of the California chapter of the American Chemical Society. Nearly forty chemists attended the first meeting in San Francisco in 1901.

Frederick G. Cottrell

The College's first entrepreneur

Frederick G. Cottrell was destined for success in the chemical sciences. Cottrell finished his undergraduate chemistry degree at Berkeley in three years in 1896. It was not atypical for him to work on problems all night in the lab. During Cottrell's third year as an undergraduate, Rising wrote to him and said, "I wish to say to you that I consider your attainments in chemistry and your faithful devotion to the science worthy of some special recognition. I have accordingly, with the consent of the President of the University, designated you Assistant to the Professor of Chemistry."

He left a Fellowship at the University to teach high school chemistry and to save enough money to do graduate work in Germany. After traveling in Europe, he settled into the lab of Wilhelm Ostwald (who won the Nobel Prize in Chemistry in 1909) in Leipzig in March of 1901 to study the "theoretical effect of the counter-flow of an electrolyte on the migration of ions through a diaphragm in an electrolytic cell." Cottrell's final oral examination for his Ph.D. was held in July of 1902. He had completed his Ph.D. in less than a year and a half and graduated *summa cum laude*.

He returned to Berkeley as a lecturer at a starting salary of $1,000 a year. In 1904 he installed the first liquid air plant on the West Coast. The plant was the start of the low temperature laboratory that later was developed and used by thermodynamicists George E. Gibson, Wendell M. Latimer and Nobel Laureate William F. Giauque.

Gilbert N. Lewis

In 1905, the Du Pont sulfuric acid plant at San Pablo Bay asked Cottrell for help with the problem of precipitating the acid mists which form when sulfur trioxide vapor is bubbled through water or dilute sulfuric acid. Cottrell determined that an electrical method, similar to one unsuccessfully tried by Sir Oliver Lodge in 1884, could be used for precipitating the mists. Thus the electrostatic precipitator was developed. Cottrell realized that considerable money was needed to purchase special equipment for the project. O'Neill and a consortium of chemists and attorneys came together and backed Cottrell's invention forming the Western Precipitation Company. With money in hand, Cottrell was able to demonstrate that every bit of the sulfuric acid in a gas current, representing 3 tons per day, could be collected with a power consumption of less than one-third kilowatt. The process was a complete success.

The electrostatic precipitator had far reaching applications pertaining to managing toxic chemical pollution. It became obvious that the patents would generate a great deal of revenue. Cottrell convinced his associates to donate the patents so scientists could use the proceeds to support future research. Cottrell worked with the Smithsonian Institution to form the Research Corporation for Science Advancement, a scientific philanthropic non-profit. The formation of the Research Corporation was a major innovation in scientific philanthropy created to utilize the proceeds of the Cottrell patents for further advancements in science and technology. One of the grants made by the corporation was for $5,500 to UC Berkeley physicist Ernest O. Lawrence to help acquire the giant magnet that was used in the construction of the first big cyclotron at Berkeley.

Cottrell left the University in 1911 and went on to a successful career in the U.S. Bureau of Mines, National Research Council and the Department of Agriculture.

Gilbert N. Lewis & the atomic era

Gilbert N. Lewis was born into the era of atomic research. Max Planck and Albert Einstein had turned physics on its ear at the beginning of the 20th Century. In 1905, Einstein introduced the concept of a "light quantum" which described the particle nature of light. Lewis would popularize the term "photon" to describe this unit of light in a 1926 letter to *Nature*.

Lewis completed his Ph.D. at Harvard in 1899 when he was 24. He then traveled to Germany and spent a year studying with Wilhelm Ostwald and Walther Nernst. After traveling, and working in the Philippines, he settled into a faculty position at MIT in 1905. In 1912, after Rising and O'Neill both canvassed UC President Wheeler, Lewis was hired and arrived on campus to take up the position of professor of physical chemistry and dean of the College of Chemistry. Lewis was elected to the National Academy of Sciences the next year.

His research was aptly summarized by Joel Hildebrand in an obituary written about Lewis, "[Lewis is associated with] the electron theory of chemical valence, the advance of chemical thermodynamics, the separation of isotopes which made possible the use of the deuteron in the artificial transmutation of the elements, and the unravelling of the complex phenomena of the adsorption, fluorescence and phosphorescence of organic dyes are among the achievements which will ever be associated with his name."

In 1902 he began to use unpublished drawings of cubical atoms in his lecture notes. In the drawings the corners of the cubes represented possible electron positions. His ongoing study led to the publication in 1916 of his classic paper "The Atom and the Molecule" in the *Journal of American Chemistry* where he described the electron-pair bond and the "rule of eight." He detailed this and other research concepts in *Valence and the Structure of Atoms and Molecules* published in 1923. Lewis co-published a review of the theory of color with Melvin Calvin in the 1930s.

Several famous chemists became faculty during the Lewis era. Nobel Laureate William F. Giauque joined the faculty in 1922, the same year he received his Ph.D. degree in chemistry with a minor in physics. He had been focused on an engineering career when he started his undergraduate work in chemistry but acquired a liking for fundamental research. He cited the emphasis on scientific investigation by the group of faculty and students associated with Lewis as the major influence for his career choice. Nobel Laureate Glenn T. Seaborg was his personal laboratory assistant from 1937 to 1939. Seaborg joined the faculty in 1939. Other faculty who started in the Lewis era included Wendell M. Latimer, Joel H. Hildebrand, G. Ernest Gibson and Nobel Laureate Melvin Calvin. Two hundred and ninety Ph.D.s were granted under Lewis and his colleagues.

According to Seaborg, in William Jolly's book *From Retorts to Lasers,* "[Lewis] to a large extent ran the College from his laboratory. I recall that his efficient secretary, Mabel Kittredge, would come into our laboratory, stand poised with her notebook until she commanded his attention, and describe clearly and briefly the matter that required his attention or decision. Lewis would either give his answer immediately or ask her to come back in a little while."

Lewis stepped down as dean in 1941 focusing on his research. In 1946, he tragically died from a heart attack in his lab. A graduate student found his lifeless body under a workbench. He had been working on an experiment with liquid hydrogen cyanide, and deadly fumes from a broken line had leaked into the room.

Contributions by the early faculty as researchers, educators and administrators in chemistry have been foundational to training world-class alumni who have excelled as researchers, faculty, and industry experts over the last 150 years. Many discoveries that changed the world were researched during the early years at the College of Chemistry. This important legacy continues through to the present day.

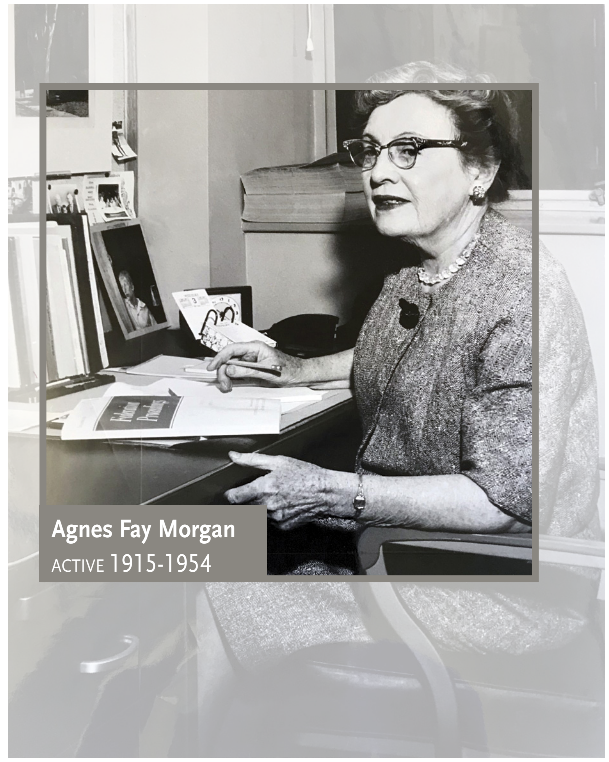
Old chemistry building c. 1897

Gilbert N. Lewis in lab c. 1944

Berkeley's first women chemists

One of the important legacies of the UC system is that women were admitted as students two years after the University's founding in 1870. The Regents unanimously passed a resolution to admit women, who made up around 36% of the state's population at the time. The University Registrar announcement was clearly meant to encourage them to attend: "Young Ladies are admitted into the University on equal terms, in all respects with young men." In fact, seven women students had already applied and been accepted before they were "officially recognized" as there was no rule stating that they could not attend.

However, hiring women faculty, especially in the sciences, lagged significantly behind the admission of women students. The first woman chemist arrived on campus in 1915. Professor Agnes Fay Morgan joined the College of Agriculture as a professor in home economics. During her tenure at Berkeley, she pioneered biochemical research in vitamins and in the understanding of how the human body processes food. Sixty-three years passed before the arrival of Professor Judith Klinman in 1978. She was the first woman physical scientist on campus. Klinman is internationally renowned for her research in enzyme catalysis. In 1983 Professor Angelica Stacy joined the College of Chemistry as an assistant professor. Today Stacy is both professor of chemistry and Berkeley's associate vice provost for the faculty. Fourth in line was the arrival of Professor Darleane Hoffman in 1984. Hoffman was hired away from Los Alamos National Laboratory by Glenn Seaborg to continue her ground-breaking research into radioactive elements. These women were pioneers, as scientists and as women faculty and helped pave the way for future generations of women faculty and students in the sciences.



Agnes Fay Morgan
ACTIVE 1915-1954

COURTESY OF UC BERKELEY DEPARTMENT OF NUTRITIONAL SCIENCES & TOXICOLOGY

Agnes Fay Morgan, (1884 – 1968) Professor Emerita Nutrition and Biochemist Emerita, Agricultural Experimentation Station, was a pioneer among women in American science. Morgan received her Ph.D. in Chemistry from the University of Chicago in 1914 and joined Berkeley's faculty the next year.

A 1949 article in *Chemical and Engineering News,* explained Morgan's reason for choosing the position at Berkeley. "After majoring in physical and organic chemistry, the new Dr. Morgan examined her fields of study and observed that there were many highly competent young men also looking for similar jobs. She decided to seek other related fields where there was less prejudice against women chemists."

Morgan was scheduled to interview with the college's dean. However, he sent his wife and teenage daughter to conduct the interview instead. They were apparently favorably impressed because she was offered a position, which she accepted for a salary of $1,800; male faculty members at the university were being paid $2,400 with a doctorate and $1,800 without one. At the time, there was a strong belief that women faculty should be unmarried when they were teaching. Morgan, however, was unusual because she was married when she accepted her faculty position.

Morgan arrived on campus only to learn that she would be teaching courses in nutrition and dietetics. Dietetics was, she said, "A subject I knew nothing about and nobody else knew much about at that time." She had to research the curriculum "mostly out of German medical journals." Her goal eventually became to "debunk, through scientific research methods, myths about common household customs of cookery, clean living and good order," and in that way promote sound practices in this "tradition-bound arena."

Some of the most significant scientific research to emerge from Morgan's laboratory concerned the biochemistry of vitamins and the nutritional value of foods. She became best known for her work examining the effects of pantothenic acid (vitamin B5) on adrenal gland function. In her early research, Morgan analyzed processed foods and characterized their vitamin composition. She was the first to establish that a preservative, sulfur dioxide, protected vitamin C but damaged thiamine.

Late in her career, she was involved in an Agricultural Experiment Station project that examined nutrition among older people in San Mateo County. That work yielded two important conclusions: that bone density began to decline in women between the ages of 50 and 65, and that dietary fat intake led to increases in serum cholesterol.

Morgan received the Garvan Medal in 1949, which is awarded to outstanding women in chemistry by the American Chemical Society. In 1954, Morgan and Wayne State University researcher Arthur H. Smith were the co-winners of the Borden Research Award from the Borden Company Foundation.

Judith Klinman
ACTIVE 1978-PRESENT

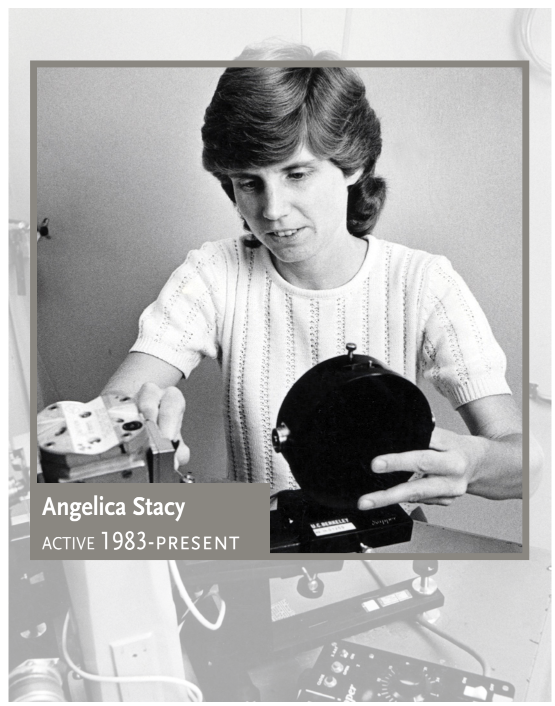
COURTESY UC BERKELEY COLLEGE OF CHEMISTRY

Judith Klinman is a Professor of the Graduate School and a Chancellor's Professor. She is Professor Emerita in Chemistry and Molecular and Cell Biology and a member of the California Institute for Quantitative Biosciences.

Among her many distinctions, Klinman was the first woman faculty member in the physical sciences at UC Berkeley. She also is the only woman to chair the Department of Chemistry, serving in that capacity from 2000 to 2003. During her tenure she has been a Chancellor's Professor, a Guggenheim Fellow, and a Miller Fellow. She was elected to the National Academy of Sciences, the American Academy of Arts and Sciences, and the American Philosophical Society, and has received the Repligen Award and the Remsen Award from the American Chemical Society.

Klinman has contributed to the understanding of the fundamental properties that underlie enzyme catalysis. Early in her career, she developed the application of kinetic isotope effects to the study of enzyme catalysis, showing how these probes can be used to uncover chemical steps, to determine kinetic order, and to obtain substrate dissociation constants. She investigates how proteins and enzymes do everything from letting our bodies use oxygen to regulating neurotransmitters. Her research looks into the fundamental properties that underlie these reactions, often using isotope tracers to uncover the chemical steps involved. These studies include the role of hydrogen tunneling and protein dynamics in enzyme catalysis; the post-translational production of novel protein and peptide-derived cofactors and their roles in enzyme function; and the underlying principles of oxygen activation among enzymes that utilize a wide range of catalytic strategies.

She was awarded the National Medal of Science in 2012 by former President Barack Obama for her discoveries of fundamental chemical and physical principles underlying enzyme catalysis and for her leadership in the community of scientists. Klinman's parents told her when she started that if a woman chose a career in science it was typically as a lab tech. "But I had this underlying curiosity," she said. "I was determined to go the whole route."



Angelica Stacy
ACTIVE 1983-PRESENT

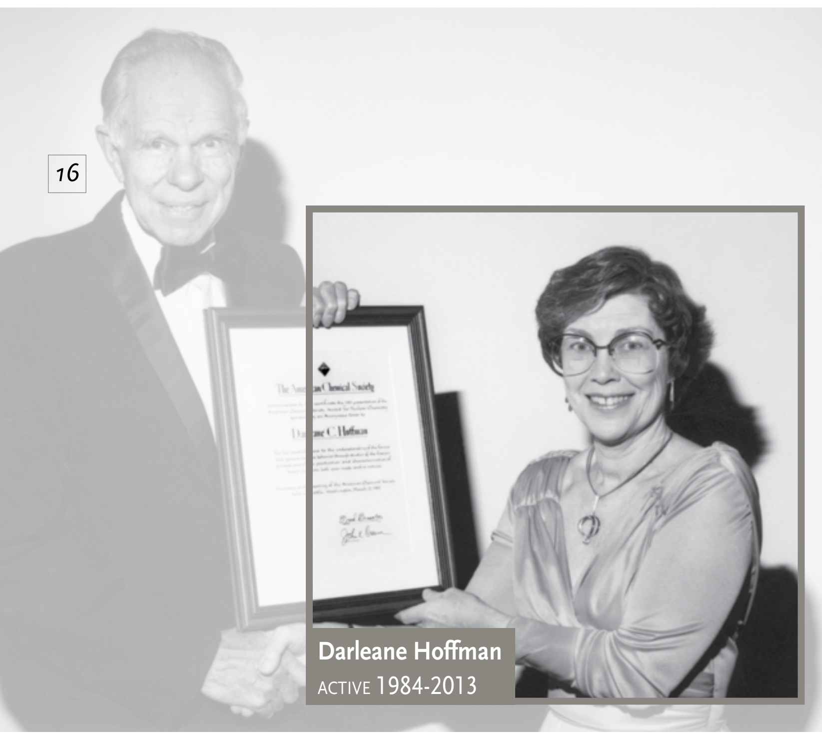
COURTESY UC BERKELEY COLLEGE OF CHEMISTRY

Angelica Stacy is a Professor of Chemistry and the UC Berkeley Associate Vice Provost for Faculty. Along with her chemistry research and teaching, she is involved in research focused on undergraduate chemistry education. Stacy joined the College of Chemistry as an assistant professor in 1983.

Stacy's chemistry research focused on development of new synthetic methodologies, including the use of molten salts for the synthesis of oxide superconductors, electrodeposition (in aqueous solutions and molten salts) for the synthesis of thermoelectric materials, and the use of plasma-solid reactions for the synthesis of fluorides with interesting catalytic properties. The lab experimented with a plasma chamber in the development of chemistries for emission reduction of perfluorocarbon compounds produced by plasma processing of semiconductor devices. Further exploration included two-dimensional and one-dimensional quantum confined thermoelectric materials.

Regarding her work for faculty inclusion Stacy says, “Diversity is an integral part of excellence. If we are to attract the best and the brightest then we need to draw on all the talented minds, not just from a few select groups. One only needs to look around at the faculty to realize that its composition does not reflect the diversity of our society, or even the diversity of our students. My post is critical in assisting our faculty and our leadership in using data to construct new paradigms for promoting greater diversity and equity in our faculty.”

Stacy has received many awards both for her chemistry research and for her work in education. She is the recipient of the President’s Chair for Teaching, University of California; Francis P. Garvan-John M. Olin Medal; Catalyst Award, Chemical Manufacturers Association; The Donald Sterling Noyce Prize for Excellence in Undergraduate Teaching; and the James Flack Norris Award for Outstanding Achievement in the Teaching of Chemistry.



Darleane Hoffman
ACTIVE 1984-2013

COURTESY LAWRENCE BERKELEY NATIONAL LABORATORY

Darleane Hoffman, Professor Emerita, Nuclear Chemistry has fundamentally added to our understanding of radioactive elements. In 1971, scientists still believed that transuranium elements did not occur in nature, but in that year Hoffman, working at Los Alamos National Laboratory, discovered small amounts of plutonium-244 in a rock formation. Hoffman also isolated and characterized fermium-257— “Work that represented a monumental advance in the understanding of the fission process,” according to Nobel Prize winner Glenn Seaborg. Hoffman was also noted for her study of the chemical and nuclear properties of rutherfordium, bohrium, and hassium, and she confirmed the existence of seaborgium.

Hoffman had not always dreamt of becoming a nuclear chemist. She originally entered Iowa State College with a major in applied art. However, a required chemistry class, and an inspirational professor, influenced her to switch majors. When her applied arts professor asked if a career in chemistry was appropriate for women, Hoffman replied, “Of course, my chemistry professor is a woman.”

This question of gender would be a recurring theme throughout her career. When she originally applied for a job in the 1950s with Los Alamos National Laboratory’s radiochemistry division, she was told that they didn’t hire women in that field. This didn’t discourage her and she became the first female division leader at Los Alamos, leading the isotope and nuclear chemistry division. According to Hoffman, “Nuclear science was started in large part by women, among them Marie Curie. If anything, women were prominent because it wasn’t an established field, and so it was easier to break into.”

In the early 1970s, Hoffman made an important discovery about nuclear fission. Scientists had known since the late 1930s that the nuclei of certain elements split when bombarded with neutrons. Hoffman discovered that the atoms of one element, fermium, could split spontaneously.

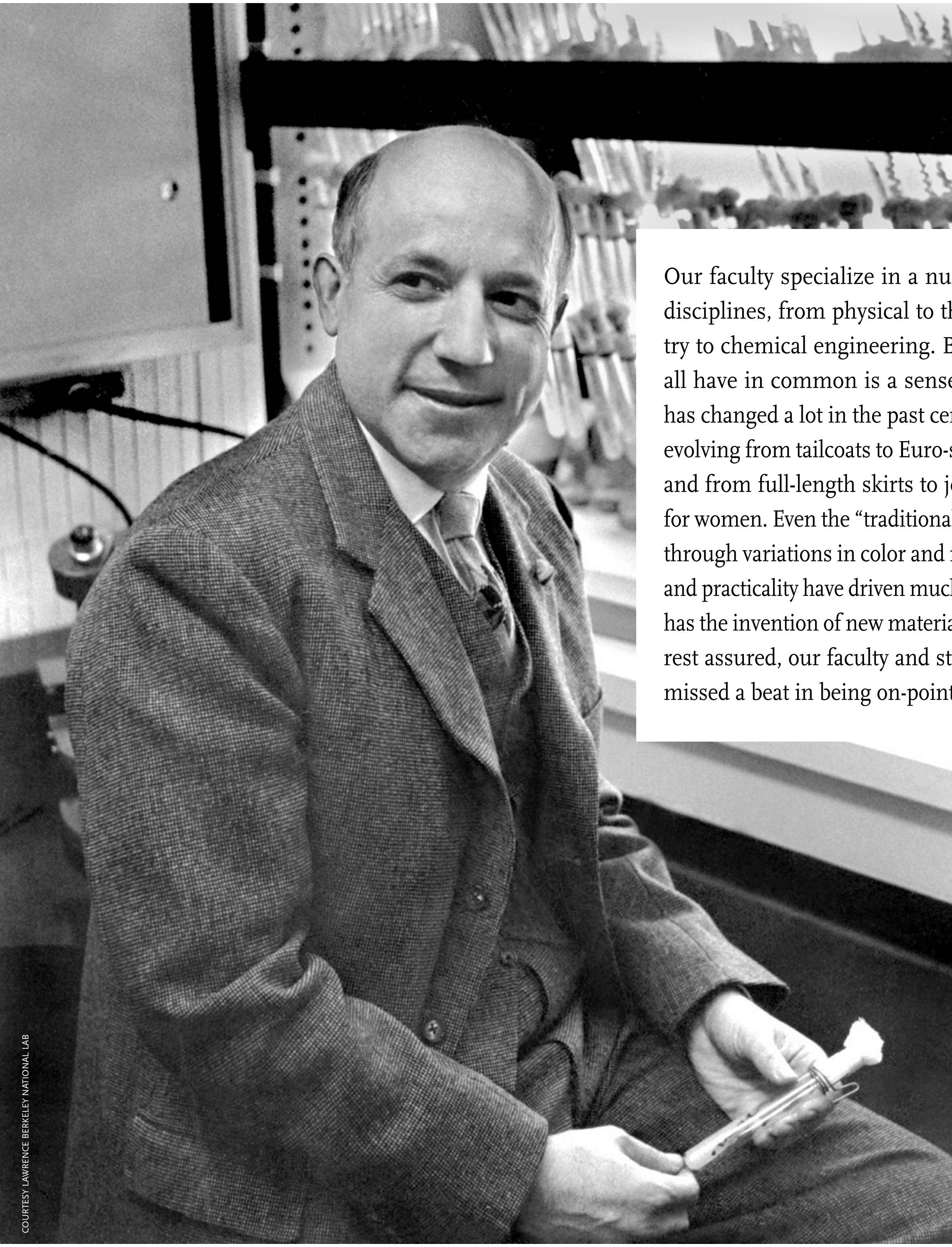
Among her many prizes, Hoffman was awarded the National Medal of Science for Chemistry by former President Bill Clinton in 1997 for her research efforts. Specifically, she was cited for her discovery of primordial plutonium in nature and the symmetric spontaneous fission of heavy nuclei; for pioneering studies of elements 104, 105, and 106, and for her outstanding service to education of students in nuclear chemistry and as director of the Seaborg Institute for Transactinium Science of the University of California.

THANK YOU!

History doesn’t “collect” itself. Building pictorial and data archives takes passion, perseverance and a keen interest in the past. We are deeply grateful to the following individuals for their aid in helping tell early stories of the College. Huge thanks to Professors Judson King, John Prausnitz, David Wemmer, Jeffrey Reimer and Judith Klinman for opening their doors and answering numerous questions about the College’s history; to the College’s former assistant dean Jane Scheiber for centralizing many early, rare College photographs; to Waverly Lowell, Curator, Environmental Design Archives, for her insights into South Hall, Gilman Hall, and the old chemistry building and for providing access to rare materials; and to current and past College of Chemistry staff members Mindy Rex, Michael Barnes and Karen Elliott for always being available to answer questions and provide mentorship.

THE BIBLIOGRAPHY for "Celebrating 150 Years of Chemistry at Berkeley" is available in the online version at chemistry.berkeley.edu/catalyst.

The fashionable chemist



COURTESY LAWRENCE BERKELEY NATIONAL LAB

Our faculty specialize in a number of chemical disciplines, from physical to theoretical chemistry to chemical engineering. But one thing they all have in common is a sense of style. Fashion has changed a lot in the past century and a half — evolving from tailcoats to Euro-style suits for men, and from full-length skirts to jeans and sneakers for women. Even the "traditional" lab coat has gone through variations in color and materials. Comfort and practicality have driven much of the diversity, as has the invention of new materials for clothing. But rest assured, our faculty and students have never missed a beat in being on-point for trends.

Nobel Laureate Melvin Calvin – publicity photo c. 1962

1880s

The first female students brought their own sense of style and panache to campus. They were generally dressed in casual Victorian clothing, spurning corsets, frills and rear-enhancing bustles for more relaxed day wear. Their attire included long narrow skirts, high-neck blouses and (very) long hair pinned up and tucked into brimmed hats known as "plugs."

1890s

Professor, and long-time dean, Gilbert N. Lewis went to Harvard. In this 1890's student portrait he looks incredibly dapper in an Edwardian sack suit made of wool. He is wearing his signature mustache that he would keep throughout his life. His stylish beard is neatly trimmed.

1900s

Classrooms were full by the 1900s with science courses well attended. In this South Hall photo, the women students are wearing coats and plugs. The men's suits are likely readymade with close-fitting jackets that buttoned to the top.

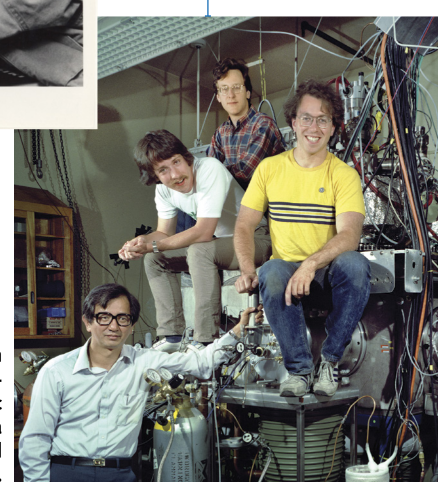
1960s

Nothing says 1960s fashion like color. Here, in vivid Kodachrome, is the element 104 discovery team (from left) Matti Nurmia, Jim Harris, Kari Eskola, Glenn Seaborg, Pirkko Eskola and Albert Ghiorso, photographed at the Berkeley Lab in 1969. Pirkko is wearing a Coco Chanel inspired green tweed suit. The men are in business wear with Jim Harris wearing a brushed cardigan and smooth sweater.

1970s

Professor Judith Klinman arrived at Berkeley in 1978. She was the first woman in materials science on campus and came with a strong sense of personal style. Jeans had become the rage for women. The New York Times declared, "The more worn in they seem, the better."

1980s

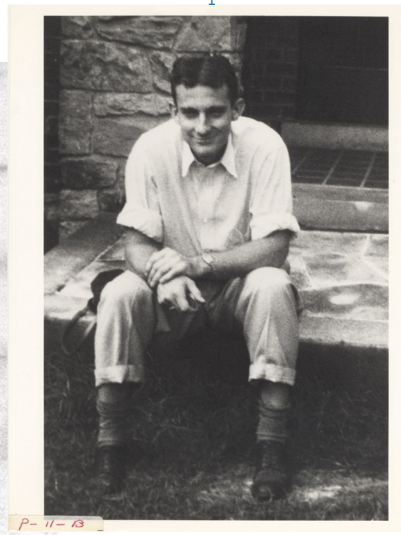


Professor and Nobel Laureate Y.T. Lee (left) is dressed in dark pants, a classic white button-down shirt, and round-rimmed glasses. His then-students on the equipment, Alec Wootke (left) Gary Robinson, and Daniel Neumark (now a professor of chemistry), sport polo and long-sleeved plaid shirts with de rigueur jeans and tennis shoes.

1920s 1930s 1940s 1950s

Men's fashion took a radical turn with the invention of Gillette's safety razor. Here, a clean-shaven Professor Joel Hildebrand is wearing a three-button suit with vest, white collar dress shirt and necktie. He is sporting rimless glasses that became the rage in the 1880s.

Professor and Nobel Laureate Glenn T. Seaborg was a strikingly tall man at 6'3". He cuts a dashing figure rushing through Sather Gate in 1938 in a trench coat and fedora.



Professor James Cason taught organic chemistry for nearly four decades at Berkeley. This 1945 photo shows him wearing a breezy summer outfit, with a button-down shirt and cuffed linen pants. He has added bold horizontal striped sport socks to complete the look.

The white lab coat had already been around for more than 100 years when this photo was taken of Professor Darleane Hoffman in her lab. She had not yet arrived at Berkeley, but her sense of style was well established by this point. Originally, lab coats were beige, but they were changed to white because it was easier to distinguish stains from spills.

1990s 2010s 2018

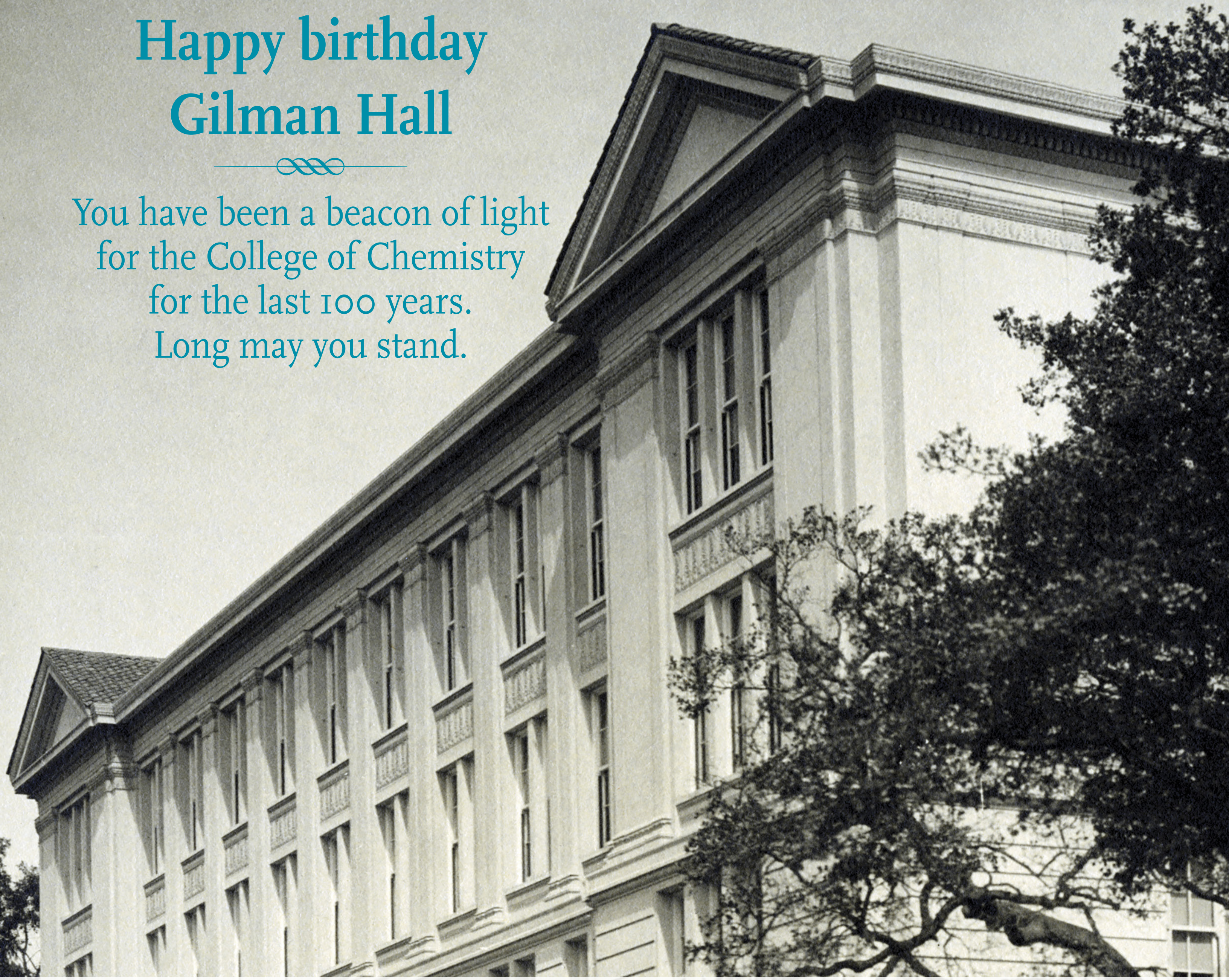
Professor Jeffrey Reimer arrives for the 1997 inauguration of Tan Kah Kee Hall dressed in a European style dark suit with black sweater. He has embellished his fashion statement by arriving on his Yamaha YZF-750.

Professors Richmond Sarpong (left) and David Wemmer attend a function in stylish modern menswear. Sarpong is wearing a slim fit suit with open shirt. Wemmer has on a western style leather sports jacket. Both are styling the ever popular 1880s rimless glasses.

A group of CBE students walk through the UC botanical garden for an AIChE field trip in early spring. Dressed for the northern California Mediterranean climate, they are wearing the current UC Berkeley uniform of shirts, ripped jeans and tennis shoes with short-waisted jackets.

Happy birthday Gilman Hall

You have been a beacon of light for the College of Chemistry for the last 100 years. Long may you stand.



Gilbert N. Lewis, the fourth dean of the College, envisioned a "large new fire-proof chemical laboratory" when he first worked with University Architect John Galen Howard on the design for Gilman Hall. Chemistry research was exploding in Europe, especially in Germany, leading up to World War I. The University wanted to capitalize on that explosion and become the cutting edge chemical research facility in the United States. For that, it needed a new building. Gilman Hall, named for UC president Daniel Coit Gilman, was built during 1916 and 1917 and dedicated in the spring of 1918.

Gilman is a classical three-story building with a red mission-tile roof. Its north and south gabled end wings flank a central facade of nine bays, defined by a row of engaged Ionic columns rising from a plinth formed by the rusticated basement.

Research which resulted in the award of two Nobel Prizes has been done in the building. Nobel Laureate William Giauque studied the properties of matter at temperatures close to absolute zero in his basement lab in Gilman Hall. He was awarded the Nobel Prize in Chemistry in 1949. The second Nobel Laureate was Glenn T. Seaborg whose lab was in 307 Gilman Hall. He won with physicist Edwin M. McMillan in 1951 for discoveries in the chemistry of the transuranium elements.

The Chemical Engineering Department (now Chemical and Biomolecular Engineering), housed in Gilman Hall, was officially recognized as a College department in 1957. Charles W. Tobias, the founding father of electrochemical engineering, had both his office and lab in Gilman Hall. His office was in the southwest corner on the first floor and his labs were at the north end of the attic on the west side.

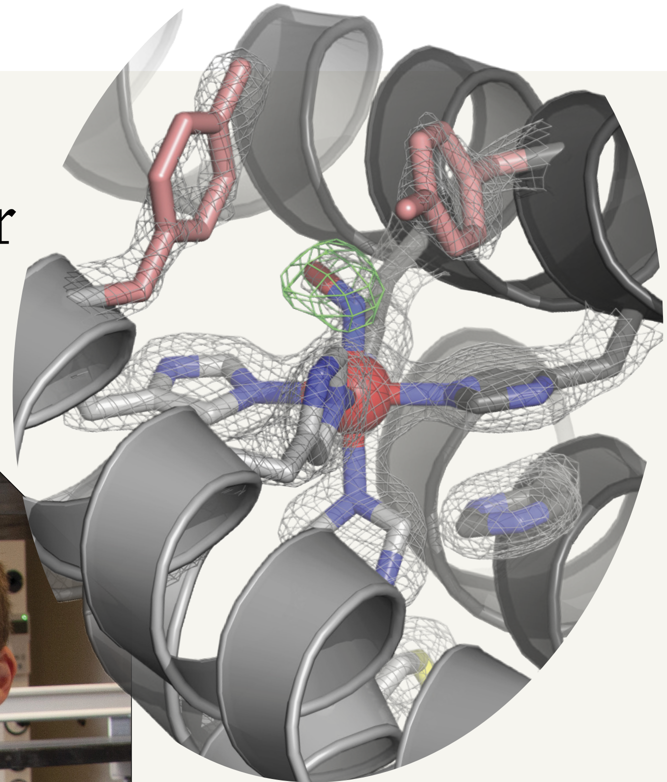
Gilman Hall c. 1919

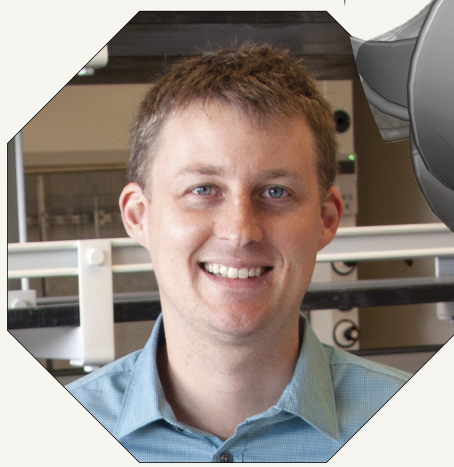
COURTESY OF THE JOHN GALEN HOWARD COLLECTION, ENVIRONMENTAL DESIGN ARCHIVES, UNIVERSITY OF CALIFORNIA, BERKELEY

BY MICHAEL BARNES

JOHN RITTLE

Putting the pieces together





Undergraduate students are rarely the first authors on articles in leading scientific journals. But that's what happened in Nov. 2010, when *Science* published an article by Jonathan Rittle, a Penn State undergrad.

Rittle impressed the scientific community by solving a long-standing mystery concerning cytochrome P450 enzymes. His sleuthing was just the start of his successful scientific career, one that will continue here at Berkeley. This July Rittle will join the College of Chemistry faculty as an assistant professor.

Rittle was born in Reading, PA, about 60 miles NW of Philadelphia. As he explains, "Reading is best known as the source for the Reading Railroad card in the game Monopoly. Although I was born there, I grew up nearby in the town of Wernersville, a town of a few thousand people, where the outskirts of suburbia meet farmland."

Like many College of Chemistry faculty members, Rittle developed his interest in research in his high school lab. "We had an excellent agricultural science program at our local high school," he explains. "The local farmers donated a lot of money to the program. We had the typical Future Farmers of America competitions, but the program wasn't just about raising animals. We grew plants in test tubes and studied microbiology and molecular biology — it was hands-on and very rigorous."

Rittle graduated from high school in 2006 and enrolled at Penn State University, where he studied chemistry in the lab of his adviser, Michael T. Green. The Green group studies metalloprotein chemistry, with an emphasis on a class of enzymes called cytochrome P450s, named for their strong spectroscopic absorption line at the wavelength of 450 nm.

The group focuses on the P450 enzymes for several reasons. They are a biologically important class of enzymes that appear in many diverse life forms. In humans, these enzymes take part in the metabolism of about 75 percent of pharmaceuticals. In addition, these enzymes catalyze the oxygenation of otherwise inert carbon-hydrogen bonds, which is, according to the group's website, "a Holy Grail of chemical synthesis."

Rittle's assignment in the Green research lab was to explore the mysterious Compound I, a critical intermediate in the activity of the P450 enzymes whose structure had flummoxed researchers for 30 years. His eventual success, which resulted in the 2010 *Science* article, is a classic example of what is known as normal science. In this often unglamorous process, dozens of researchers, working over many years, keep adding pieces to the puzzle, until one day the picture becomes clear. Says Rittle, "For me it was a combination of luck and meticulous science. Thanks to the encouragement of my adviser Michael Green, I was the one who finally was able to put all the pieces together and confirm the result."

In 2010, with his Penn State chemistry B.S. in hand, Rittle began his chemistry Ph.D. studies at Caltech. There he worked in the lab of Jonas Peters, another chemist with an interest in metalloenzymes. (Peters had been a Miller Fellow at Berkeley, where he worked with Professor of Chemistry Don Tilley.) Rittle's area of research was understanding and developing catalysts that fix nitrogen.

Rittle began studying synthetic model complexes of nitrogenase as a grad student at Caltech. It was a task that took him back to his roots in the Pennsylvania farmland. He says, "Humans have figured out how to convert atmospheric nitrogen into ammonia and fertilizers via the Haber-Bosch process. But this process requires high temperatures and pressures and must be done on a large scale."

"If we could learn to mimic the action of nitrogenases, we could have local, distributed ammonia production under normal temps and pressures. It's something you could do on a farm, maybe in conjunction with solar power. This could be a good model for Africa and other developing regions where farmers lack access to commercial fertilizers. An added benefit is that ammonia can be used as a biofuel."

In 2016 Rittle completed his Ph.D. thesis, "Proton-Coupled Reduction of N2 Facilitated by Molecular Fe Complexes." Says Rittle, "In my Ph.D. research I synthesized metal complexes that mimic the structure and functionality of nitrogenases." He was one of three recipients of Caltech's 2016 Herbert Newby McCoy Award, which is given in recognition of outstanding achievement in research by chemistry graduate students.

Adds Rittle, "While I learned a lot, and I hope my work provides a basis for further research, we have a long way to go before we can use nitrogenase-based enzymes as substitutes for the catalysts used in Haber-Bosch."

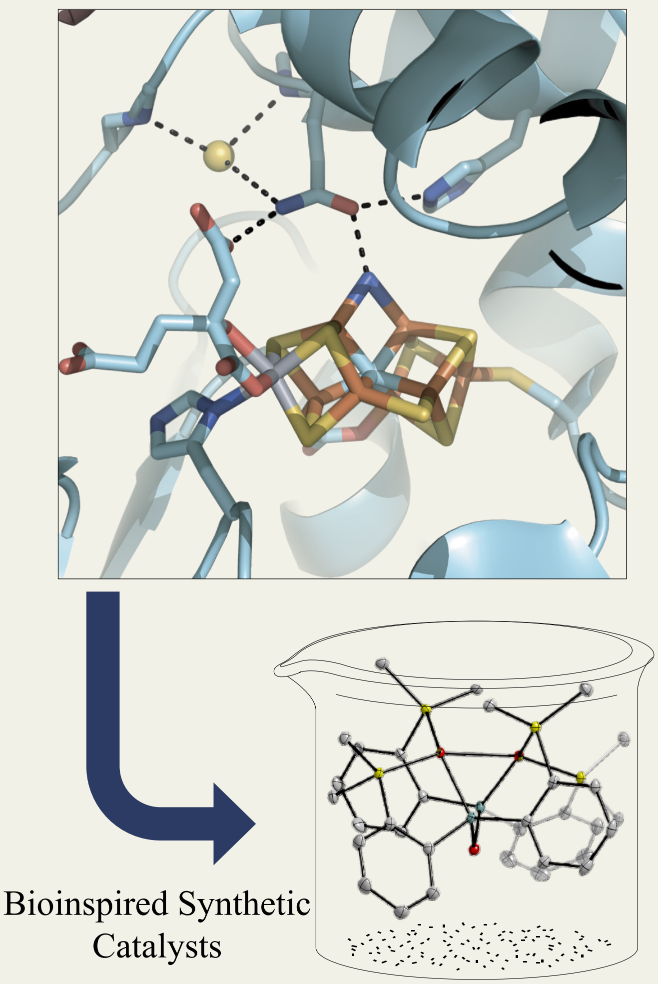
For his postdoctoral research, Rittle chose to work with the group of chemist Akif Tezcan at UC San Diego. He explains, "I chose the Tezcan lab because, although the group shared my interest in metalloproteins and nitrogenases, the researchers there were more focused on synthesizing novel protein structures, including those that can support catalytic activity, like enzymes. I wanted to learn how to make new protein structures."

Rittle is now commuting between San Diego and Berkeley, measuring his new lab space and meeting with incoming students and prospective group members to tell them about his research program.

Says Rittle, "Here is what I tell students: Research in my group will focus on unique metalloenzymes composed of earth-abundant transition metal ions. We want to understand how their active sites functionalize unreactive organic molecules and develop new strategies to synthesize reactive inorganic cluster compounds. Our long-term goal is to develop powerful and selective synthetic catalysts that use multiple transition metal ions to inspire new therapeutic strategies and useful chemical processes."

"Researchers in the lab will use the tools of synthetic chemistry, structural biology and various spectroscopic methods to explore molecular and electronic structures. To facilitate these investigations and to expand upon the diverse biocatalytic potential of these enzymes, we will develop biosynthetic and computational strategies to rationally improve the stability and solubility of these enzymes."

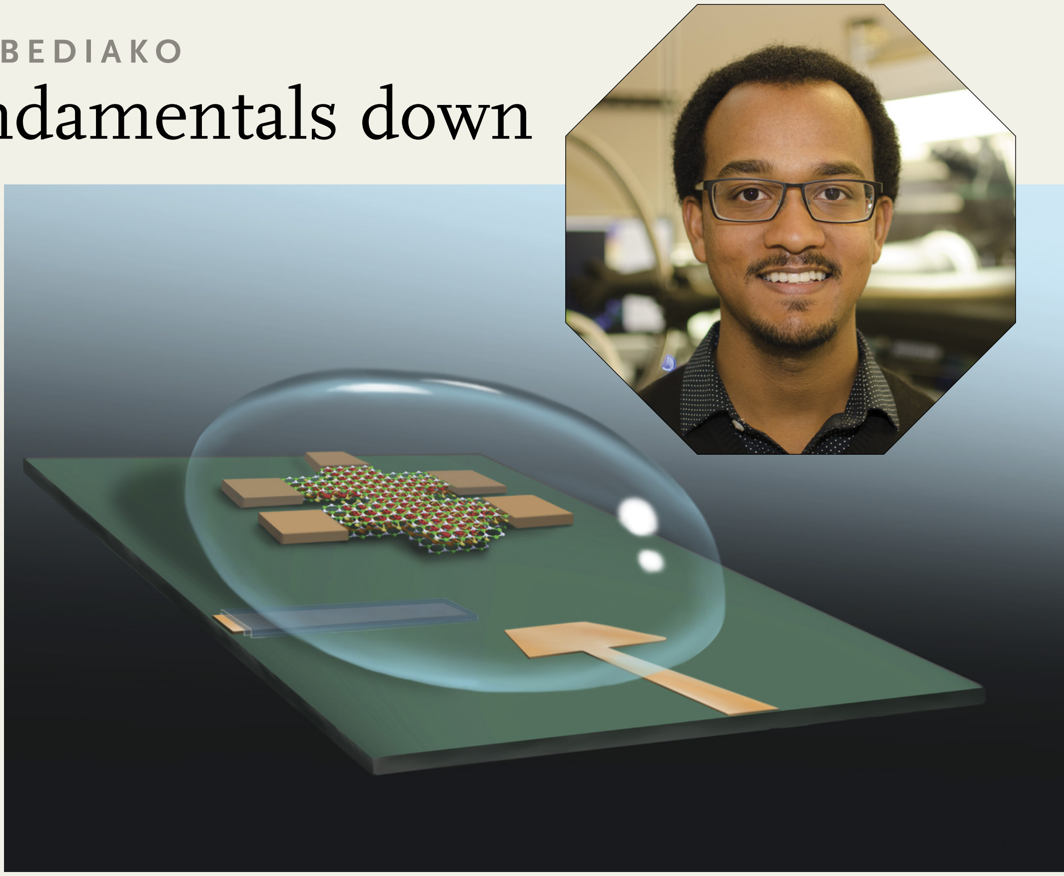
Looking back on his career to date, Ritter reflects, "Although my hometown of Wernersville was on the edge of farm country, it was still just about an hour's drive to Philadelphia. There were many diehard Philadelphia Eagles football fans in town, including my father. I was happy for him that he finally got to see the Eagles win the Superbowl. As a scientist, I think there's a lesson there. Like the Eagle's victory, science takes years of perseverance, some good coaching, and in the end, a bit of luck."



Nature has created powerful biocatalysts like the cytochrome P450 and nitrogenase enzymes. The Rittle lab strives to understand how these complex molecules work in order to create simple synthetic versions from inexpensive and abundant precursors.

KWABENA BEDIAKO

Getting the fundamentals down



"In Ghana," says Kwabena Bediako, one of the College of Chemistry's new assistant professors, "everyone knows I was born on Tuesday." Bediako, whose first name is pronounced Kwab-na, continues, "There is a tradition in Ghana to name children by the day of the week they were born. So we know Kofi Annan, the former U.N. Secretary General, was born on Friday, and our first president, Kwame Nkrumah, was born on Saturday."

Although born in Ghana's capital city of Accra in 1986, Bediako's upbringing was international. His British mother met his Ghanaian father in Bordeaux, France, where they were both studying French. His father was studying for his first Ph.D. in African francophone literature. Both parents would go on to earn Ph.D.s in theology.

Bediako did spend time in his mother's hometown of Blackburn, just north of Manchester, and in Edinburgh, Scotland. He also accompanied his father to Pasadena, CA, where he was lecturing. "But whenever I returned to Ghana, I would get off the plane in Accra and the humidity would greet me with a big warm hug." That memory provided him with some comfort when he found himself attending a small midwestern college, where his campus job over the winter was shoveling snow.

Bediako grew up an hour north of Accra in the town of Akropong, and attended middle and high school at the Akosombo International School, another hour further north. "The school in Akosombo," he says, "was created to educate the children of the expatriates who came there to build a huge hydroelectric dam on the Volta River." Completed in 1965, the dam created Lake Volta, which has the largest surface area of any artificial lake in the world.

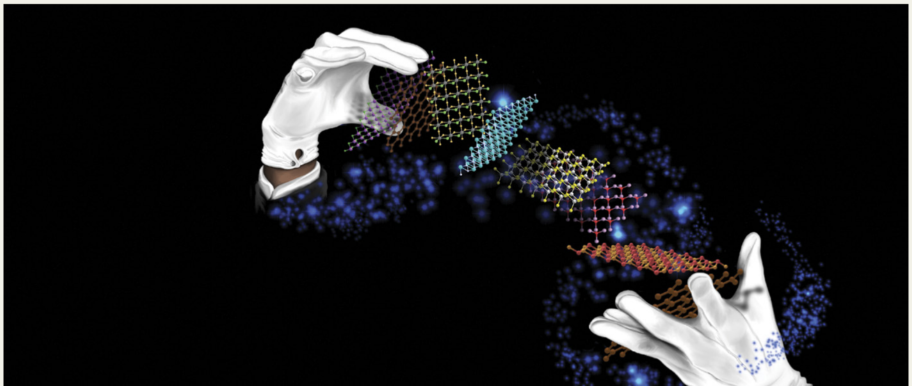
Although the dam provided cheap electricity for both aluminum smelters and Ghana's power grid, it had some unintended consequences, including providing habitat for mosquitos. "When I was in school in Akosombo," Bediako recalls, "we got malaria about as often as Americans get the flu. This left a strong impression on my older brother, Yaw, who also studied there. He became an immunologist who researches malaria in Kenya and the U.K."

Bediako finished his high school studies in 2004. He states, "I became intrigued by chemistry in high school, thanks to my teacher Charles Karikari. However, I didn't have the opportunity to spend time in a lab." Bediako moved to the United States to begin his college career at Calvin College, a small religious liberal arts college in Grand Rapids, MI. He says. "At Calvin, I had a great inorganic chemistry professor, Douglas Vander Griend, and I became fascinated with inorganic coordination chemistry. I wrote an undergrad thesis with Vander Griend as my adviser, and along with other students, I co-authored two published papers with him."

Graduating with a chemistry B.S. in 2008, Bediako was ready to move onto graduate school when he changed course, moved to suburban Chicago, and, began working for Honeywell UOP. "I made catalysts and absorbents and spent a year getting some industry experience. I figured I'd spent several years in academia, so I wanted to know what it was like on the other side of the fence."

In 2009, Bediako began his Ph.D studies at MIT, where he worked with Dan Nocera. "I was interested in energy and the environment. There wasn't much solar power in Ghana, and I wondered why. The Nocera lab was working on water splitting with cobalt and other metal catalysts for solar energy storage, culminating in an artificial leaf."

In 2013, Nocera moved to Harvard, and Bediako moved with him. "I got my master's at MIT in 2013, and my Ph.D. at Harvard in 2015," he says. Bediako's thesis was entitled "The Electrocatalytic Evolution of Oxygen and Hydrogen by Cobalt and Nickel Compounds."



The Bediako lab works its magic by starting from nanoscale building blocks and creating electrochemically active structures in the mesoscale range, where quantum mechanics give them unique functionality.

About his thesis research Bediako says, "Artificial photosynthesis requires the execution of two half-reactions, one that oxidizes water to O_2 — the oxygen evolution reaction — and the other that reduces hydrogen ions to H_2 — the hydrogen evolution reaction. My oxygen evolution reaction studies focused on the catalytic behavior of structurally disordered first-row transition metal oxides.

"At a fundamental level, understanding how protons and electrons may be managed and coupled to improve their activity is important for the design of new electrocatalysts. I enjoyed working on a problem that was motivated by renewable energy, but also involved learning very fundamental mechanistic details of how bonds are rearranged to make new molecules."

For his postdoc, Bediako remained at Harvard, but switched from chemistry to physics. He worked in the lab of Phillip Kim, which was focused on properties of low-dimensional nanoscale materials. The group uses modern semiconductor fabrication techniques to make materials based on carbon nanotubes, organic and inorganic nanowires and two-dimensional crystals.

In the language of physics, macroscopic objects exhibit behaviors that can be explained by classical mechanics. As these objects get smaller (while they are still composed of many molecules), they enter the mesoscopic realm where the explanation of their behavior requires quantum mechanics.

Says Bediako, "In the Kim lab, we started with a clear mesoscopic target and asked, can we make it? It is possible to make some nanoscale and larger mesoscale structures by deposition from liquid-phase suspensions. These techniques are scalable, but the processes are random enough that you're never quite sure what structures you created.

"In the Kim lab, I learned how to isolate the layers of our nanoscale lattices and precisely place them to create superlattices. That appeals to me. These techniques might not scale at this point in time, but to understand the fundamentals you have to know what you are working with. And who knows, in the future we may find that it's possible to layer these materials on a massive scale like we do the pages of a newspaper.

Says Bediako, "Not only are there thousands of layered materials to choose from, at the nanoscale we have some extra tricks to help expand the nature of the structures we create — quantum confinement effects, strong electronic correlations and van der Waals forces. These van der Waals forces can act over atomic distances and can lead to additional modifications to the heterostructure lattices. We can also insert atoms, ions and molecules into the van der Waals gap between layers. The structures I create are called layered van der Waals crystals or van der Waals heterostructures.

"If you have ever seen a gecko climb a wall, or scamper across a ceiling, you've seen van der Waals forces in action," he adds. "The geckos have special structures on their toes that allow them to use these forces to cling to surfaces.

"I think from an early age I appreciated that academic research, and the process of searching for answers to questions about the world around us, has great intrinsic value. I came to recognize that it is just as worthwhile to be a chemist in a lab as it is to be a doctor in a hospital. I don't think that was a common point of view among Ghanaian kids when I was younger. Back then, if you were interested in science, you studied to become a doctor or engineer. So like my parents, I ended up in academia — but I felt drawn to become a scientist and not a theologian."

Bediako will officially join the faculty on July 1, although he has already made several visits from Harvard to talk with students about his research program. Here's how he explains the goals of his lab: "Research in my group will involve the mesoscopic investigation of charge transfer and charge transport in two-dimensional materials and heterostructures, with an emphasis on studying electrochemical energy conversion in fuel cells, batteries and other energy applications. We'll also study two-dimensional semiconductors and quantum electronics. Many of the challenges to creating new materials for energy conversion are related to challenges in next-generation electronics and computing as well.

"To do this, we'll synthesize and isolate atomically thin inorganic crystals, precisely assemble these layers into novel multicomponent materials and use them to build electrochemical and electronic devices. We will employ a range of optical spectroscopy, electron microscopy, and low-temperature quantum probes to measure the properties of these devices. Working as chemists we'll study how to manipulate the interfaces of materials to overcome problems at the interface of chemistry and physics."

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PAGE 10 & 11: Robert A. Fisher, Ezra S. Carr, Willard B. Rising, John M. Stillman and Edmond O'Neill; private collection, College of Chemistry, UC Berkeley; South Hall c. 1900, Berkeley Public Library, accessed March 16, 2018. https://oac.cdlib.org/ark:/13030/kt009nc6xf/?brand=oac4

PAGE 12 & 13: Frederick G. Cottrell, Gilbert N. Lewis, old chemistry building and Gilbert N. Lewis in lab; private collection, College of Chemistry, UC Berkeley.

PAGE 14 & 15: Agnes Faye Morgan, collection of Agnes Fay Morgan, UC Berkeley, Bancroft Library, BANC PIC 1975.057; Judith Klinman and Angelica Stacy; private collection, College of Chemistry, UC Berkeley

PAGE 16 & 17: Darleane Hoffman and Glenn Seaborg, Berkeley Lab, accessed March 16, 2018. http://photos.lbl.gov/bp/#/folder/126413/4655546; Melvin Calvin, 1962, Berkeley Lab, accessed March 16, 2018. http://photos.lbl.gov/bp/#/folder/127170/

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PAGE 20: Gilman Hall c. 1919, John Galen Howard Collection, Environmental Design Archives, UC Berkeley.

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California Nobel Prize winners with their family members and dogs c. 1998. Professor Glenn Seaborg and family in the back row; Henry Taube (Ph.D. '40) standing in suit on the far right.

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