Department of Chemistry

In academic year 2012–2013, the Department of Chemistry had 24.5 full-time faculty (including one dual faculty appointment with the Department of Biological Engineering): five assistant, one associate, and 18.5 full professors. Three of our faculty (Catherine Drennan, Alexander Klibanov, and JoAnne Stubbe) have a secondary appointment in the Department of Biology or the Department of Biological Engineering. Three additional faculty (Arup Chakraborty, Barbara Imperiali, and Steven Tannenbaum) have a secondary appointment in the Department of Chemistry. In addition to research in biological, inorganic, organic, materials and nanoscience, and organic and physical chemistry, the Department of Chemistry continued its strong programs in undergraduate and graduate education, with 214 graduate students, 110 postdoctoral researchers, and 67 undergraduate chemistry majors.

Effective July 1, 2013, professor Mohammad Movassaghi assumed the rank of full professor.

The department is delighted to welcome Yogesh Surendranath, who will join the faculty as an assistant professor on July 1, 2013. Dr. Surendranath is a Miller Postdoctoral Fellow at the University of California, Berkeley, with professor Paul Alivisatos. The Surendranath group will focus on addressing global challenges in the areas of chemical catalysis, energy storage and utilization, and environmental stewardship. Fundamental and technological advances in each of these areas require new methods for controlling the selectivity and efficiency of inner-sphere reactions at solid-liquid interfaces. The group's strategy will emphasize the bottom-up, molecular-level engineering of functional inorganic interfaces, with a current focus on electrochemical energy conversion.

The department is also delighted to welcome Adam Willard, who will join the faculty as an assistant professor, on July 1, 2013. Dr. Willard is a postdoctoral scholar at the University of Texas at Austin, with professor Peter Rossky. The Willard group will use theory and simulation to explore the role of molecular fluctuation in a variety of chemical phenomena, with a particular interest in systems for which a mean field approach, i.e., the averaging out of molecular-level detail, fails to reproduce experimental results. This is often a consequence of complex molecular scale behavior such as collectivity, spatial or dynamic heterogeneity, or the coupling of fast and slow time or length scales, which can give rise to interesting and unexpected macroscopic phenomena.

Susan Solomon, the Ellen Swallow Richards professor of atmospheric chemistry and climate, has accepted a joint appointment as professor with the Department of Chemistry and will take up her appointment on July 1, 2013. Research in the Solomon group includes three primary components, two of which are disciplinary, and a third that extends into new interdisciplinary directions: (1) advancing the understanding of chemistry-climate coupling and climate predictability on time scales ranging from decades to millennia, (2) better quantifying ozone depletion chemistry and its linkages to climate change, and (3) identifying climate change impacts on human society and

nature, particularly the signals of anthropogenic changes that are emerging or will soon emerge from the noise of internal variability.

Faculty Awards and Honors

On April 30, 2013, Robert Field, the Haslam and Dewey professor of chemistry, was elected to the National Academy of Sciences (NAS). Election to NAS—a private organization of scientists and engineers dedicated to advancing science and its use for the general welfare—is considered a top honor for those in the science and engineering fields. Established in 1863, NAS acts as an official adviser to the federal government, upon request, in any matter of science or technology. Current and emeritus faculty members in the Department of Chemistry who are NAS members include professors Robert Alberty, Moungi Bawendi, Klaus Biemann, Stephen Buchwald, Sylvia Ceyer, Barbara Imperiali, Alex Klibanov, Stephen Lippard, Richard Schrock, Dietmar Seyferth, JoAnne Stubbe, Timothy Swager, and John Waugh.

The Awards Committee of the Royal Society of Chemistry's Dalton Division announced on April 29, 2013, that it had selected professor Christopher Cummins for the 2013 Ludwig Mond Award. Professor Cummins was selected for his work in unparalleled synthetic, mechanistic, and reactivity studies of low-coordinate early-transition or actinide metal complexes containing unusual main-group ligands to discover novel chemistry of small molecules, including N2, N2O, CO, CO2, and P4. Professor Cummins also won the inaugural American Chemical Society (ACS) Inorganic Chemistry Lectureship Award; he was nominated by his peers for his creativity, rigor, and record of research success in the field of inorganic chemistry.

On June 6, 2013, *Chemical and Engineering News* announced that Professor Lippard, the Arthur Amos Noyes professor of chemistry, would be the recipient of the 2014 Priestley Medal, ACS's most prestigious honor. Professor Lippard is being recognized by ACS "for mentoring legions of scientists in the course of furthering the basic science of inorganic chemistry and paving the way for improvements in human health."

In May 2013, Professor Lippard was selected as the 2013 recipient of the James R. Killian Jr. Faculty Achievement Award. Each year the Killian Award Selection Committee chooses one member of the MIT faculty to be the Killian Award Lecturer for the following academic year. The award was established in spring 1971 as a permanent tribute to James R. Killian, Jr., president of the Institute from 1948 to 1959 and chairman of the MIT Corporation from 1959 to 1971. The purpose of the award is to recognize extraordinary professional accomplishments by MIT faculty members and to communicate these accomplishments to members of the MIT community. Professor Lippard is widely acknowledged as one of the founders of the field of bioinorganic chemistry.

On May 30, 2013, Harvard University conferred honorary degrees on six men and three women, one of whom was JoAnne Stubbe, the Novartis professor of chemistry and professor of biology at MIT. Professor Stubbe has developed a body of successful research that shows the power of chemistry to solve some of biology's most pressing problems. Her most noted work explains how nature harnesses the reactivity of free radicals to carry out complex, highly specific chemistry.

In February 2013, the Alfred P. Sloan Foundation announced its selection of early-career scientists and scholars for 2013 Sloan Research Fellows. The recipients are drawn from 61 colleges and universities across the US and Canada. Among those selected was Elizabeth Nolan, the Pfizer-Laubach Career Development professor of chemistry. Sloan Research Fellowships are given to early-career scientists and scholars whose achievements and potential identify them as rising stars among the next generation of scientific leaders.

The Damon Runyon Cancer Research Foundation announced, on January 4, 2013, that seven scientists with novel approaches to fighting cancer were named 2013 recipients of the Damon Runyon-Rachleff Innovation Award. Professor Bradley Pentelute was among the seven selected. The award is designed to provide support for the next generation of exceptionally creative thinkers with high-risk/high-reward ideas that have the potential to significantly impact our understanding of and/or approaches to the prevention, diagnosis, or treatment of cancer.

Professor Matthew Shoulders was selected in June 2013 as the 56th Edward Mallinckrodt Jr. Foundation Faculty Scholar. The mission of the Mallinckrodt Foundation is to support early-stage, highly promising investigators engaged in basic or clinical research that has the potential to advance the understanding, diagnosis, or treatment of disease.

Carolyn Bertozzi (on right), the T.Z. and Irmgard Chu distinguished professor of chemistry and professor of molecular and cell biology at the University of California, Berkeley; investigator at the Howard Hughes Medical Institute; and senior faculty scientist at the Lawrence Berkeley National Laboratory, visited the department on May 2–3, 2013, to deliver the Büchi Lectures in Organic Chemistry. To the left of her is Dr. Louise Foley, a former graduate student of George Büchi.

Named Lectures

The department welcomed the following named speakers during fall 2012 and spring 2013:

- Merck-Banyu Lecture: Ryo Shintani, Kyoto University
- Davison Lectures in Inorganic Chemistry: Gerard Ferey, Université de Versaille Saint-Quentin
- Novartis Lecture in Organic Chemistry: Scott Miller, Yale University, and Christopher Straub, Novartis

- Bristol-Myers Squibb Lecture in Organic Chemistry: Tobias Ritter, Harvard University, and Jeffrey Robl, Bristol-Myers Squibb
- Merck-Karl Pfister Lectures in Organic Chemistry: Christopher Bielawski, University of Texas at Austin
- Boehringer-Ingelheim Lecture in Organic Chemistry: Dean Toste, University of California, Berkeley, and Jeff Song, Boehringer-Ingelheim
- T.Y. Shen Lectures in Biological Chemistry: Squire Booker, Pennsylvania State University

Serving the Institute

The Department of Chemistry provides key educational service to the Institute. During AY2013, the department taught 1,993 undergraduate students in the areas of biochemistry and inorganic, organic, and physical chemistry. The department also was home to 62 Undergraduate Research Opportunities Program (UROP) students, providing important mentoring relationships for students from a number of departments, including Chemistry, Biology, Mathematics, Physics, Chemical Engineering, Electrical Engineering and Computer Science, Materials Science, and Mechanical Engineering.

Chemistry Majors

The department continues to consistently attract a talented group of undergraduates to Course 5, with a total of 67 majors across the three years. This year, 27 students received bachelor of science degrees in Chemistry. In exit surveys, it was found that 52% of the Class of 2013 is bound for graduate school, 11% plan to attend medical school, 7% will seek employment, and 30% did not indicate their plans.

Class of 2013. Back row (L–R): Elijah Mena, Rocco Policarpo, Ted Li, Michael Desanker, Seva Ivanov, Bryan Changala, Tea Dorminy, Wen Chyan, Samuel Thompson. Front row (L–R): Merricka Livingstone, Annie Dunham, Jared Forman, Erin O'Brien, Clarissa Forneris, Masha Kulikova. Missing from photo: Taylor Ayral, Rachel Bandler, Linh Bui, Rebecca De Las Cuevas, Brendan Deveney, Lauren Garcia-Spite, Maya Hubbard, Ruben Jauregui, Amy Lin, Armiyaw Sebastian Nasamu, Omokaro Osazuwa, Hamza Sheikh.

Undergraduate Awards

Undergraduate awards were given at the 2013 Undergraduate Senior Recognition and Awards Banquet in May:

Alpha Chi Sigma Award for outstanding achievement in scholarship, research, and service to the department—P. Bryan Changala, Wen Chyan

Research Award for outstanding contributions in the area of research—Linh Bui, Rocco Policarpo, Samuel Thompson

Department of Chemistry Service Award for significant contributions in the area of service to the department—Rachel Bandler, Rocco Policarpo

Outstanding Senior Thesis—P. Bryan Changala

Strem Prize in recognition of the best undergraduate research presentation at the Chemistry UROP Symposium—Clarissa Forneris

ACS Analytical Chemistry Award for outstanding achievement by a junior in experimental chemistry—Katherine Silvestre

Sophomore Achievement Award for outstanding performance in academics, research, and service to the department—Khetpakorn Chakarawet, Martin McLaughlin

CRC Freshmen Chemistry Achievement Award for outstanding academic achievement in chemistry—Diptarka Hait

ACS Inorganic Chemistry Award for excellence in inorganic chemistry—Wen Chyan

ACS Organic Chemistry Award for outstanding achievement in organic chemistry—Clarissa Forneris

Hypercube Scholar Award for outstanding contribution to the advancement of computers in teaching—Anubhav Sinha

Undergraduate Research Opportunities Program

The Undergraduate Research Opportunities Program continues to be a capstone experience for undergraduates. With over 90% of chemistry majors working in a research group at least once during their degree program, students have the unique opportunity to conduct research alongside faculty, postdoctoral researchers, and graduate students.

Chemistry Teaching Assistants

The Department of Chemistry's graduate student teaching assistants (TAs) are among the best at MIT. This year, students gave 67% of the department's TAs a 6.0 or higher rating on a 7.0 scale. Of those TAs in this percentile, more than half received a 6.5 rating or higher.

Comments from Student Evaluations

[My TA] is fantastic! He explains material very concisely in a way that's easy to understand, and his examples and practice problems are great.
Best TA I've had! Amazing, accessible, and helpful.

I love [my TA]!!! She is such a great TA. Sometimes I would have absolutely no clue what was going on in the class and it seemed like a different language, but [she] would explain it in a way that I somehow understood it. I used to hate chemistry so much in high school and thought I was awful at it, but [my TA] has made me start to enjoy it and I look forward to recitations with her so that I can learn more :)

Great TA! Has amazing and very helpful recitations, from which you learn so much more than from lectures and the textbook. Presents a very good summary of the material and makes you think logically about the reactions and mechanisms that happen. He is by far the best TA I've had so far!

Great TA! Really helped me learn lab techniques, was fun to have as a lab TA, and was very helpful when we made mistakes. Best lab TA I've had at MIT so far.

Graduate Student Awards

Experimental Nuclear Resonance Conference Ritchey Travel Award—Loren Andreas

MIT 100K Business Plan Awardee—Joseph Azzarelli

Johnson Fellowship—Josh Baraban

Outstanding Teaching Award—Megan Brophy, Andrew DiChiara, Xiaodi (Angela) Gao, Tsehi Grell, Grace Han, Pornchai Kaewsapsak, Ken Kawamoto, Eric Keeler, Petra Lindovska, Sarah Luppino, Thomas (Andy) McTeague, Notaree Niljianskul, Charles Ocampo, Daniel Rowlands, Ryan (Spencer) Shinabery, Prasahnt Sivarajah, Molly Sowers, Jonathan Truong

Eni-MIT Energy Fellowship—Leora Cooper, Aaron Goodman, Thanasak Sathawitaya

National Science Foundation Graduate Research Fellowship—Igor Coropceanu, Kurt Cox, Owen Fenton, Sarah Luppino, Jolene Mark, Christopher Moore, Hyun Duk Shin, Colby Steiner

63rd Lindau Meeting Delegate—Jian Cui, Marco Jost

Materials Research Society Fall Meeting Graduate Student Award (Silver)—Jian Cui

C.P. Chu and Y. Lai Summer Graduate Fellowship—Andrew DiChiara, Toshiki Nakshige

Astra-Zeneca Summer Graduate Fellowship—Xiaodi (Angela) Gao, Jenny Liu, Alex Vinogradov

School of Science Underrepresented Minority Fellowship—Tsehai Grell, Pablo Ricardo

Amgen Summer Graduate Fellowship—Philip Hamzik, Chi Zhang

Presidential Fellowship—Laurel Heckman, Jun Jiang, Ken Kawamoto, Petra Lindovska, Sarah Park, Peter Richter, Elizabeth Wittenborn

Amy Lin Shen Summer Graduate Fellowship—Elizabeth Hocking

International Precious Metal Institute–Gemini Graduate Student Award—Timothy Johnstone

MIT Poitras Fellowship—Marco Jost

Ludo Frevel Crystallography Scholarship—Marco Jost

Ann and Paul Steinfeld Memorial Summer Graduate Fellowship—Ken Kawamoto

Natural Sciences and Engineering Council of Canada Fellowship—Jenny Liu

Masamune Summer Graduate Fellowship—Mike Lu

Dow Fellowship—Marie Mackenzie

Strem Summer Graduate Fellowship—Michelle MacLeod

Daniel S. Kemp Summer Graduate Fellowship—Surin Mong

School of Science Fellowship—Christopher Moore

Walter L. Hughes Memorial Summer Graduate Fellowship—Christopher Moore

PTT Public Company Limited Fellowship—Notaree Niljianskul

Stephen J. Lippard Summer Graduate Fellowship—Ryan Palmer

George H. Büchi and Kin-Chun T. Luk Family Summer Graduate Fellowship—Mark Simon

Department of Chemistry Graduate Summer Fellowship—Molly Sowers

Optical Terahertz Science and Technology Poster Award—Stephie Teo

ACS Division of Organic Chemistry Travel Award—Ekaterina Vinogradova

Samsung Scholarship—Hyunsuk Yoo

International Workshop on Optical Terahertz Science and Technology

The International Workshop on Optical Terahertz Science and Technology (OTST) 2013 was held from April 1–5, 2013, in Kyoto, Japan. Morse Travel Fund grants enabled four graduate students from the Keith Adam Nelson group to attend: Jian Lu, Stephanie Teo, Nathaniel Brandt, and Benjamin Ofori-Okai. OTST showcases the frontier of terahertz (THz) research, and the students were excited about participating.

Stephanie Teo presented a poster titled "Development and Analysis of Single-shot Detection Methods for Multidimensional THz Spectroscopy," which focused on a novel detection scheme for expediting THz measurements to a fraction of the acquisition time of traditional methods. She was awarded one of the distinctions for "most impressive poster presentation," with 12 presenters awarded from nearly 200 judged presentations.

Harold Hwang, PhD '12, a former graduate student in the Nelson group and now a postdoctoral researcher in the Nelson group, jointly with Boston University Photonics Center faculty Richard Averitt and Xin Zhang, also attended OTST. He was one of the

12 presenters awarded the distinction for "most impressive poster presentation," for his poster titled "Metamaterial-enhanced Nonlinear Responses in Semiconductors as a THz Detection Platform." He also gave an oral presentation titled "Nonlinear Dynamics of High Temperature YBCO Superconductors Probed with THz Time Domain Spectroscopy."

Professor Keith Nelson's group attending the International Workshop on Optical Terahertz Science and Technology in Kyoto, Japan. From left to right: Stephanie Teo, Harold Hwang, Jian Lu, Professor Nelson, Nate Brandt, unknown, and Ben Ofori-Okai.

The title of Jian Lu's talk was "THz-driven Soft Mode Dynamics in SrTiO3 Observed by Optical Second Harmonic Generation," and he described his work with Professor Nelson on developing a time-resolved spectroscopy technique and how it was used to study the dynamics of the soft phonon mode, i.e., a lattice vibration mode, in quantum paraelectric SrTiO3. The electric fields of the THz pulse were used to excite the lattice vibrational motion, which breaks the inversion symmetry of the crystal lattice. Optical second harmonic generation was used to probe the induced symmetry breaking due to lattice vibration, and a time domain signal oscillating at the lattice vibration frequency was observed. A future plan is to pump the system harder and observe nonlinear lattice vibration behavior, which may shed light on the role of lattice vibration in some structural phase transitions.

Benjamin Ofori-Okai was invited to give a talk, which he titled "Experimental Band Structure Measurement of THz Photonic Crystal Slabs." His work focuses on time-resolved measurement of photonics crystals, which are effectively the light-based analog to semiconductors. He spoke on how he studied the propagation of THz fields through these systems and used this information to better understand how photonics crystals work, and how they have the potential to lead the way towards new devices as demands of technology increase.

Nathaniel Brandt gave a talk titled "Nonlinear 2-D and 3-D Metamaterials on Silicon," which detailed recently observed nonlinear THz transmission in metamaterial antennas patterned on silicon wafers. This revealed information regarding the behavior of electrons in silicon under very strong transient electric fields. He also presented a poster titled "THz-induced Decomposition of Organic Crystalline Materials," which highlighted recent progress made in the Nelson group towards inducing chemical reactions with strong THz fields.

Doctoral and Master's Degree Recipients

September 2012

Kozera, Daniel*	SM	Schrock group
Li, Meiyi	SM	Lippard group
Park, SeMi	PHD	Lippard group
Top, Laken	SM	Van Voorhis group
White, Katharine	PHD	Ting group
Wolfson, Mikhail	PHD	Chakraborty group
Fenton, Owen**	SM	Movassaghi group

February 2013

Bediako, Daniel*	SM	Nocera group
Chen, Zhao	SM	Bawendi group
Hanson, Christina**	SM	Nocera group
Lemon, Christopher*	SM	Nocera group
Narayan, Tarun	SM	Dinca group
Ofori-Okai, Benjamin**	SM	Degen group
Ramashesha, Krupa	PHD	Tokmakoff group
Shaver, Rachel	SM	Field group
Sydlik, Stephanie	PHD	Swager group
Tanuwidjaja, Jessica	PHD	Jamison group
Tsay, Charlene	PHD	Peters group
Uttamapinant, Chayasith	PHD	Ting group
Zou, Peng	PHD	Ting group

June 2013

Arias, Dylan	PHD	Nelson group
Batson, Joel Marcus	PHD	Swager group
Burts, Alan	SM	Johnson group
Chambers, Matthew Burke	PHD	Nocera group
Colombo, Anthony	PHD	Field group
Goldman, Peter John	PHD	Drennan group
Kim, Justin	PHD	Movassaghi group
Larson, Alyssa Maxine	PHD	Klibanov group
Lee, Jungmin	PHD	Bawendi group
Medley, Jonathan William	PHD	Movassaghi group
Morey, Shannon Marie	SM	Hammond group
Senecal, Todd	PHD	Buchwald group
Teverovskiy, Georgiy	PHD	Buchwald group
Tofan, Daniel	PHD	Cummins group
Weight, Alisha Kessel	PHD	Klibanov group
Wen, Patrick	PHD	Nelson group
Wilson, Justin Jeff	PHD	Lippard group
Wolfson, Johanna	PHD	Nelson group
Yao, Zhengzheng	PHD	Ting group

Yost, Shane Robert	PHD	Van Voorhis group
Zimanyi, Christina Marie	PHD	Drennan group

*Continuing at other institution
** Continuing at MIT (with different adviser)

Faculty Research Highlights

Sylvia Ceyer

The Ceyer group has continued to observe that hydrogen dissolves into the bulk of a Au-Ni surface alloy. This alloy is an excellent model for the Raney Ni alloy, used commercially in all heterogeneous catalytic hydrogenation reactions. The possibility of enhanced solubility of hydrogen in this Ni alloy, as compared with pure Ni, promises to make "bulk hydrogen" available for study by the larger community. The Ceyer group has also been probing the role of collisional lattice activation in the surface reactivity of Si. Preliminary results reveal that this mechanism for activation is a general one for covalently bound surfaces that serve as a reactant.

Christopher Cummins

Thermodynamic and kinetic parameters were determined for oxygen atom transfer reactions involving N-O bonds. New molecular species were synthesized to serve as precursors to reactive intermediates containing phosphorus. Molecular precursors to phosphide semiconductor nanoclusters were designed and synthesized, and new cyclophosphate structures were synthesized and investigated as ligands for transition metals. Systems for studying electron transfer from a peroxide dianion receptor complex were developed.

Mircea Dinca

The Dincă group reported the first two examples of highly porous metal-organic frameworks that can exhibit large charge mobility. These are the first electrical conductors in a class that contains several thousand compounds. The Dincă group also made the first thiophene-based covalent organic frameworks (this report received the cover page of the *Proceedings of the National Academy of Sciences*), an important step towards testing new material architectures for organic photovoltaics. Additionally, the group demonstrated that metal-organic frameworks are more structurally dynamic and water-stable than previously thought, with potential implications in the design of new heterogeneous catalysts.

Catherine Drennan

The diverse reactivity of *S*-Adenosylmethionine (AdoMet) radical enzymes allows for the production of chemically complex biomolecules and the maintenance of cellular processes that are essential for life. In the last year, the Drennan lab provided three firsts for this 48,000-membered superfamily: the first structure of an anaerobic Sulfatase Maturing Enzyme (SME), the first structure of an AdoMet radical dehydrogenase, and the first structure to display the fold of the so-called SPASM domain. SME uses its

dehydrogenase activity to co-translationally modify a Ser/Cys residue on a sulfatase, generating a catalytically essential formylglycyl residue. In humans, inhibition of sulfatase activity leads to disease, whereas in bacteria, inhibition impairs colonization of the mucosal layer of the human gut.

John Essigmann

The Essigmann group discovered that 5-chlorodeoxycytosine, a product of DNA damage by inflammation, is strongly mutagenic. This finding helps explain the link between inflammation and certain gastrointestinal cancers. Essigmann group members also collaborated with the Andrei Tokmakoff laboratory to probe the underlying mechanism of action of an antiviral agent, 5-aza-6-dihydrocytosine, which is in late-stage clinical trials for the human immunodeficiency virus (HIV). They found that the drug candidate adopts multiple interchanging tautomeric forms, some of which are mutagenic. The data explain the mutagenic properties of the compound, which causes HIV to evolve so quickly in cell culture that it goes extinct after about 20 replicative cycles. This is an antiviral strategy that mimics the action of our innate immune system.

Robert Field

The Field group's study of the *trans-cis* transition state as it is sampled in the spectra of electronically excited acetylene reveals two new universal classes of patterns diagnostic of unimolecular isomerization. Chirped Pulse millimeter-Wave spectroscopy of photolysis products demonstrates how the geometric structures of photofragmentation transition states are encoded by vibrational level population distributions. The group's study of core-nonpenetrating Rydberg states provides a complete picture of the electronic structure of a molecular cation and the mechanisms by which this structure is perturbed by an external electron.

Timothy Jamison

The Novartis-MIT Center for Continuous Manufacturing team demonstrated the first end-to-end continuous manufacturing of a pharmaceutical drug substance. The Jamison group developed the chemical synthesis sequence utilized in the process. In collaboration with Klavs Jensen and Allan Myerson (both of the Department of Chemical Engineering), the group developed an integrated, end-to-end system for the continuous manufacturing of several (i.e., multiple) pharmaceutical substances in a refrigerator-sized system containing several new innovations and technologies for continuous flow synthesis. Potential applications are in the areas of disaster relief, developing nations, green manufacturing, and orphan/neglected diseases. The group also developed a new family of nickel complexes that is expected to find broad utility in catalysis.

Stephen Lippard

Methanotrophic bacteria consume methane as their major carbon source and play an essential role in the global carbon cycle by limiting escape of this greenhouse natural gas to the atmosphere. In the first step of the process, an enzyme known as soluble methane monooxygenase uses atmospheric oxygen to convert methane to methanol, which is then used to produce all the biomass of the organism. The enzyme comprises

three proteins that work in concert as an amazing molecular machine to accomplish this difficult chemical first step. During the past year, the Lippard laboratory used X-ray crystallography to solve the longstanding puzzle of how two of these proteins come together during the catalytic cycle to control the timed entry of the methane, oxygen, and protons to a pair of irons atoms at the active site of the enzyme that activate oxygen for methane to methanol conversion.

Mohammad Movassaghi

Research in the Movassaghi lab continues to focus on the development of new strategies and technologies for complex molecule synthesis. The group recently reported the first general approach to the total synthesis of bionectin A and bionectin C, providing a general solution to the challenging C12-hydroxylated tetracyclic diketopiperazines. It also provided a new solution for thiolation of diketopiperazine alkaloids and reported on its findings in the context of the interrupted Bishler-Napieralski reaction. Importantly, the group completed and reported on a four-year study involving the first comprehensive structure-activity-relationship study of epipolythiodiketopiperazine alkaloids that show potent activity against five human cancer cell lines. The hallmark of the lab's syntheses is their unparalleled efficiency and high level of stereochemical control in most complex settings, taking full advantage of the inherent chemistry of plausible biosynthetic intermediates.

Elizabeth Nolan

The Nolan group established that the antimicrobial protein human calprotectin employs the flexible C-terminal tail of the S100A9 subunit to provide a unique hexahistidine site for manganese (II) coordination in solution, and demonstrated that the tail region is important for antibacterial action against both Gram-negative and -positive species *in vitro*. In studies of the cysteine-rich antibacterial peptide human defensin 5 (HD5), the laboratory prepared an unprecedented dimeric form where two HD5 monomers are linked by intermolecular disulfide bonds. This species is highly protease-resistant and exhibits enhanced antibacterial activity against the human pathogen *Acinetobacter baumanni* compared with the parent peptide. In another thrust, antibiotic-enterobactin conjugates were prepared and enterobactin-mediated delivery of the toxic cargo across the Gram-negative outer membrane via the FepA receptor of pathogenic *Escherichia coli* was achieved.

Matthew Shoulders

The Shoulders lab initiated a research program focused on understanding protein folding in cells, developing chemical biology-based methods to regulate the cellular protein folding machinery, and establishing novel therapeutic strategies for protein misfolding-related diseases. Highlights in the first year include the establishment of a sophisticated model system to explore protein misfolding associated with the abundant and currently incurable collagenopathies, and the development of methods to quantitate protein misfolding in live cells.

Timothy Swager

The Swager group continues to produce new types of chemical sensors based upon nanomaterials. Last year, the group demonstrated a new manufacturing method wherein sensors are drawn in a solvent-free process. This method enables distributed automated manufacturing of sensors for on-demand applications, and when paired with other group technology to detect ethylene, a small molecule plant hormone, it is ideal for large-scale agricultural markets.

Alice Ting

The laboratory of Alice Ting published on two new technologies derived from a plant enzyme (ascorbate peroxidase). The first technology, published in *Nature Biotechnology*, is a method to visualize specific cellular proteins by electron microscopy, using a genetic peroxidase tag that is analogous to the widely used green fluorescence protein tag for fluorescence microscopy. The second technology, published in *Science*, is a method to proteomically map spatially-defined regions of living cells, via covalent tagging of proteins in the immediate vicinity of a genetically targeted peroxidase reporter, for subsequent mass spectrometric identification.

Sylvia T. Ceyer
Department Head
John C. Sheehan Professor