Department of Chemistry

This report summarizes achievements and noteworthy events during the 2010–2011 academic year for Chemistry Department faculty and students at the Massachusetts Institute of Technology.

Department faculty currently consists of 31 full-time faculty: two assistant, three associate, and 24 full professors, one of whom is also an Institute Professor. Of the department's 12 emeritus professors, one is an Institute Professor. In addition to research in biological, inorganic, organic, and physical chemistry, in the past year the Chemistry Department continued its strong programs in undergraduate and graduate education, with 197 graduate students, 130 postdoctoral researchers, and 86 undergraduate chemistry majors.

Effective July 1, 2011, professor Jianshu Cao will assume the rank of full professor and professors Alice Y. Ting and Elizabeth M. Nolan will take up appointments as the Ellen Swallow Richards Chair and the Pfizer Laubach Career Development Chair, respectively. Drs. Jeremiah A. Johnson and Bradley L. Pentelute will join the faculty as assistant professors.

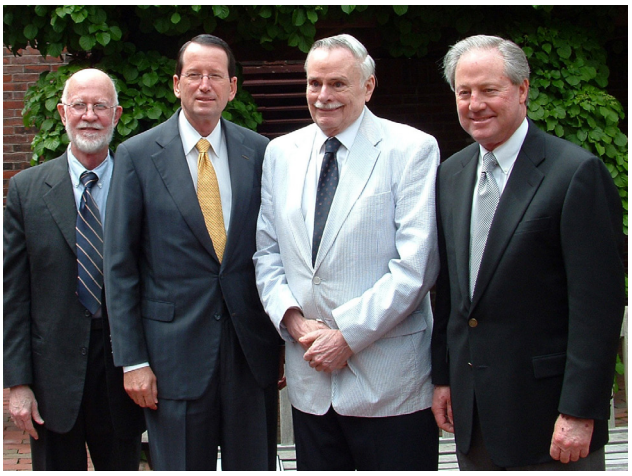
Dr. Johnson attended Washington University in St. Louis where he received a BS in biomedical engineering and chemistry in 2004. He obtained his PhD in chemistry at Columbia University in 2009. Research in Dr. Johnson's laboratory seeks to creatively integrate the tools of living polymerization, organic synthesis, microbiology, surface science, and photochemistry to solve problems at the interface of chemistry, biology, and materials engineering. Novel combinatorial synthetic schemes are employed to generate libraries of nanoscopic and bulk materials for structure/function correlation in specific applications that include drug delivery, tissue engineering, biological imaging, sensing, catalysis, and energy conversion.

Dr. Pentelute carried out his undergraduate studies at the University of Southern California, obtaining a BS in chemistry and a BA in psychology in 2003. He received a PhD in chemistry from the University of Chicago in 2008. Dr. Pentelute's goal is to develop an interdisciplinary laboratory of chemists and biologists who create the next generation chemical biology toolsets to understand virulence factors and D-proteins. He is working on a solution to the unsolved problem of delivering stable, nonimmunogenic, bioactive protein molecules to the cytosol of mammalian cells for therapeutic purposes. This goal will undoubtedly necessitate the development of new concepts and techniques in chemical biology.

Highlighted Faculty Awards and Honors

Institute Professor and professor emeritus of chemistry John S. Waugh learned in April that he was to be the 2011 recipient of the prestigious Welch Award. Many of the past half century's discoveries in chemistry, physics, biology, and materials science have flowed in part from John S. Waugh's pioneering work in nuclear magnetic resonance (NMR). His theoretical and experimental breakthroughs revolutionized the field of NMR

spectroscopy, one of science's most powerful and widely used research tools. The Welch Foundation, one of the oldest and largest sources of private funding for basic research in chemistry, honors Dr. Waugh with the $300,000 Welch Award in Chemistry for his contributions to basic research that benefits humankind.



Pictured at a luncheon to announce the Welch Award on May 12, 2011: James L. Kinsey, chairman of The Welch Foundation's scientific advisory board and former head of the MIT Department of Chemistry; Norbert Dittrich, president of The Welch Foundation; John Waugh, emeritus professor of chemistry, MIT; and Ernest Cockrell, chairman of The Welch Foundation.

JoAnne Stubbe, Novartis professor of chemistry and professor of biology, whose work over the past four decades has had profound impacts on fields ranging from cancer drug development to synthesis of biodegradable plastics, was named MIT's James R. Killian Jr. Faculty Achievement Award winner for 2011–2012. The award was announced at the faculty meeting on May 18. Established in 1971 as a tribute to MIT's 10th president, the Killian Award recognizes extraordinary professional accomplishment by an MIT faculty member. The winner is asked to deliver a lecture in the spring term. The citation describes Stubbe as the "quintessential MIT faculty member." "In all aspects of her research and teaching, her approach is packed with energy and meticulous in the attention to detail with uncompromising standards," the citation read. "Her tour-de-force discoveries are the result of elegant experimental design, deep chemical and biological insight, and a remarkable degree of focus and effort, fueled by her scientific curiosity and desire to decipher nature's secrets."

Professor Elizabeth Nolan was selected as a 2011 Searle Scholar. The prestigious Searle Scholars Program makes grants to selected academic institutions to support the independent research of outstanding individuals who have recently begun their first appointment at the assistant professor level and whose appointment is a tenure-track position. The award, $100,000 per year for three years, will support Professor Nolan's research on the metal-ion scavenging and redox regulatory functions of protein components of the human innate immune response.

Open House Day—A Great Success

The Department of Chemistry hosted several events at the Institute-wide Open House on April 30. Professor Dick Schrock gave a talk on why he became a chemist. Professor Dietmar Seyferth gave a presentation on the history of chemistry at MIT, and Dr. John Dolhun, in his "Marvelous Molecules in Play," demonstrated a selection of live interactive chemical reactions including colorful transformations, smoking balloons, invisible gases, magical polymers, flaming vapors, chemiluminescence, simulating the colors of fireworks, colorful electrolysis of water, and many more. The lobby of Building 18 showcased graduate student posters and a poster from the X-Ray Diffraction Facility.

Panel 1: John Dolhun demonstrates hydrogen peroxide molecules in play. Panel 2: Darcy Wanger (Bawendi Group) enthralls a young listener. Panel 3: Dick Schrock tells the story of how and why he became a chemist. Panel 4: Dietmar Seyferth delivers his lecture on the history of the Department of Chemistry.

Diversity

On March 2, the Dow Chemical Company announced the establishment of the MIT-Dow Outreach Fund designed to develop and support the science and engineering careers of underrepresented minorities and women. The fund, a five-year, $2 million commitment from the Dow Chemical Company, will support the advancement of the shared goal of Dow and the Massachusetts Institute of Technology of supporting science education throughout the entire pipeline, beginning with high school science teachers and their students and following through to undergraduate and graduate education in chemistry, chemical engineering, and materials science. The establishment of this outreach program came as Dow celebrated the International Year of Chemistry and the importance of the chemical sciences and as MIT celebrated its 150th anniversary.

Pictured at a luncheon at MIT to announce the multiyear collaboration: Timothy M. Swager, John D. MacArthur professor of chemistry; Klavs F. Jensen, professor of materials science and engineering and Warren K. Lewis professor of chemical engineering and head of the Department of Chemical Engineering; Theresa Kotanchek, vice president, sustainable technologies and innovation sourcing, Dow Chemical Company; Cecilia D'Oliveira, executive director of MIT OpenCourseWare; Sylvia T. Ceyer, J. C. Sheehan professor of chemistry and head of the Department of Chemistry; Catherine Hunt, director, innovation sourcing and sustainable technology, Dow Chemical Company; and Edwin L. Thomas, Morris Cohen professor of materials science and engineering and head of the Department of Materials Science and Engineering.

Professors Cathy Drennan, Judith Klinman, the T.-Y. Shen lecturer in biological chemistry, and JoAnne Stubbe

Named Lectures

The following speakers gave named lectures in the Chemistry Department during the academic year:

Francois Diederich, Swiss Federal Institute of Technology (ETH)—The Merck-Pfister Lectures in Organic Chemistry

Justin DuBois, Stanford University—George Büchi Lectures in Organic Chemistry

Matthew Gaunt, University of Cambridge, and Stefan Peukert, Novartis —Novartis Lectures in Organic Chemistry

Hans Joachim Freund, Fritz-Haber-Institut der Max-Planck Gesellschaft—A. D. Little Seminars in Physical Chemistry

Judith Klinman, University of California, Berkeley—T. Y. Shen Lectures in Biological Chemistry

James L. Leighton, Columbia University, and Martin D. Eastgate, Bristol-Myers Squibb —Bristol-Myers Squibb Lectures

David MacMillan, Princeton University—MIT-Pfizer Seminar in Organic Chemistry

Beat H. Meier, ETH—A. D. Little Lectures in Physical Chemistry

Yoshiaki Nakao, Kyoto University—Merck-Banyu Lecture

Chris Orvig, University of British Columbia—Davison Lecture in Inorganic Chemistry

C. N. R. Rao, Jawaharlal Nehru Centre for Advanced Scientific Research—A. D. Little Lectures in Inorganic Chemistry

Jin-Quan Yu, Scripps Research Institute—Boehringer-Ingelheim Lecture

Undergraduate Education

Serving the Institute

The Department of Chemistry provides a key educational service to the Institute. During AY2011, the department trained 2,650 MIT undergraduate students in the areas of biochemistry, inorganic chemistry, organic chemistry, and physical chemistry. The department also was the home for 69 students in the Undergraduate Research Opportunities Program (UROP), providing important mentoring relationships for students from a number of departments, including chemistry, biology, mathematics, physics, chemical engineering, electrical engineering, materials science, and mechanical engineering.

Chemistry Majors

As of July 2011, we have a total of 86 majors, with an average of 30 majors per class. In February and June of 2011, a total of 21 students received SB degrees in chemistry. In exit surveys this year, we found that 53% of the Class of 2011 is bound for graduate school, 20% plan to attend medical school, 13% will seek employment, and 13% are undecided.

Cambridge-MIT Exchange Program

This year we sent one chemistry major to the University of Cambridge and hosted one Cambridge student in the department.

Student Awards and Recognition

The 2011 Undergraduate Senior Recognition and Awards Banquet was held on May 12 at the R&D Common Era in the Stata Center. The following awards were presented:

Alpha Chi Sigma Award for outstanding achievement in scholarship, research, and service to the department—Alex T. Vai

Research Award for outstanding contributions in the area of research—Chase T. Anderson, Andrew J. Musacchio

Merck Index Award for outstanding scholarship—Patricia A. Hagen, Alex T. Vai, Jose L. Villa-Uribe

Frederick D. Greene Teaching Award for outstanding contributions in the area of teaching—Jonathon T. Gunn, Juliann L. Reardon

Department of Chemistry Service Award for significant contributions in the area of service to the department—Rashida A. Callender, Marie K. Herring, Victoria Wang

American Chemical Society (ACS) Analytical Chemistry Award for achievement by a junior in analytical chemistry—Daniel S. Levine

Strem Prize in recognition of the best undergraduate research presentation at the UROP Symposium on April 23—Brian McCarthy

Sophomore Achievement Award for outstanding performance in academics, research, and service to the department—P. Bryan Changala, Jared M. Forman

CRC Freshman Chemistry Achievement Award for outstanding academic achievement in chemistry—Daniel A. Mokhtari

Chemistry majors who served this past academic year as tutors and as Course V Ambassadors and Chemistry Magic Show performers were also recognized at the senior banquet.

Graduate Student Teaching Assistants

The Chemistry Department Teaching Assistant (TA) Training Program, now in its 25th year, has become the gold standard for the Institute. Thanks to the help of the instructors in the MIT Teaching and Learning Lab and the commitment of former TAs, the program continues to excite and instruct graduate students on how to provide a classroom experience for their students that is interactive, engaging, and challenging.

Over the past five years, we have seen a steady increase in TAs receiving a 6.0 or higher on a 7.0 scale in their course evaluations. Even more exciting is a steady decline in TAs receiving a 5.0 or lower rating. This year, 26% of our TAs received a 6.5 or higher rating; 64% received a 6.0 or higher; only 7% received a 4.9 or lower. The previous year, 59% received a 6.0 or higher and 14% received a 4.9 or lower.

What is behind these shifting statistics? We continue to perfect our TA Training Program. This past year, we included more team building forums with experienced TAs, as well as a new diversity workshop developed by one of our graduate students, Weslee Glenn, and professor Cathy Drennan and Dr. Elizabeth Taylor. These new additions, coupled with superb sessions with Dr. Sanjoy Mahajan from the Teaching and Learning Lab, gave our TAs the tools they needed to excel.

Student comments about their TAs:

> First recitation I ever attended more than 3x and I'm a senior thanks :)
>
> [My Chemistry TA] is great! He cares a lot about his students. He finds ways to help students who are struggling. He uses great examples in recitation that really emphasize the important concepts that we should know. His office hours are the most well attended, since he helps us with the psets but also explains the concepts along the way to make sure that we understand the underlying reasons for what we're writing down.
>
> Often, the right TA can be pivotal for one's success in a class. I have said that about some of my TAs in the past, and I can certainly say that about [my Chemistry TA]. His recitations were phenomenal: not that biochemistry could ever be boring, but he even made the most complicated reaction mechanism incredibly interesting.
>
> Some aspects of [my Chemistry TA's] teaching that I especially liked were: *his tendency to insert small tangential facts that made the original topic more accessible without detracting from the classes main focus *his strong organic chemistry background, which made his biochemistry instruction more sound *he is very good at highlighting what key points you should take away from a topic *he finds biochemistry completely fascinating *he is very meticulous about his mechanisms *he places a LOT of emphasis on class participation *general approachability and coolness

Undergraduate Research Opportunities Program

UROP remains the capstone experience for our undergraduates. With over 90% of our majors working in a research group at least once during their degree program, they have the unique opportunity to conduct research alongside faculty, post docs and graduate students.

Course V Events

The majors are active promoters of chemistry and gave tours throughout the year to many high school students interested in attending MIT. They were on hand to talk with freshmen at the Academic Expo in August, the Majors Fair in November, the UROP Fair in January, and the Freshman Open House in March. They also entertained children and their parents with the Chemistry Magic Show during Family Weekend in October (one of the most popular events offered at MIT during this weekend) and were instrumental in the success of the department's participation in the MIT150 Open House in April.

Graduate Awards and Fellowships

Tim Adams (Movassaghi Group)—Walter L. Hughes Memorial Summer Fellowship

Megan Brophy (Nolan Group)—MIT Presidential Fellowship

Hang Chen (Cao Group)—Ann and Paul Steinfeld Memorial Summer Fellowship

Junwon Choi (Fu Group)—Kwanjeong Educational Foundation Fellowship

Joseph Cotruvo (Stubbe Group)—National Defense Science and Engineering Graduate Fellowship

Jian Cui (Bawendi Group)—National Science Foundation (NSF) Graduate Research Fellowship

Joseph S. Elias (Dincă Group)—NSF Graduate Research Fellowship

Kelvin Frazier (Swager Group)—MIT Presidential Provost Fellowship

Michael Funk (Drennan Group)—NSF Graduate Research Fellowship

Daniel Graham (Nocera Group)—MIT Energy Initiative (MITEI) Energy Fellowship, NSF Graduate Research Fellowship

Ggoch Ddul Han (Swager Group)—Presidential Fellowship

Sunkyu Han (Movassaghi Group)—Kenneth M. Gordon Summer Fellowship

Eric Hontz (Van Voorhis Group)—MITEI Energy Fellowship

Andrew Horning (Nocera/Tokmakoff)—Department of Energy (DoE) Science Graduate Fellowship

Harold Hwang (Nelson Group)—Ann and Paul Steinfeld Memorial Summer Fellowship

Meiyi Li (Lippard Group)—Daniel S. Kemp Summer Fellowship

Minyuan (Miller) Li (Dincă Group)—Strem Family Summer Fellowship

Jose Lobez (Swager Group)—International Leadership Award, Friends of Todai

Vinita Lukose (Imperiali Group)—TA Award

Jeffrey Martell (Ting Group)—MIT Edward Clark Walsh Presidential Fellowship, NSF Graduate Research Fellowship

Mikael Minier (Lippard Group)—NSF Graduate Fellowship

Anna Jolene Mork (Swager Group)—MIT Chapin Fellowship

Ben Ofori-Okai (Degen Group)—Henry A. Hill Fellowship

Lisa Olshansky (Nocera Group)—NSF Graduate Research Fellowship, MIT Presidential Fellowship

Ishan Patel (Tidor Group)—DoE Science Graduate Fellowship

Amy Rabideau (Ting Group)—NSF Graduate Research Fellowship, Robert T. Haslam (1911) Presidential Fellowship

Daniel Rowlands (Ceyer Group)—MIT Energy Fellowship, Corning Fellowship

Todd Senecal (Buchwald Group)—Martin Family Society of Fellows for Sustainability, David A. Johnson Summer Graduate Fellowship

Eric A. Standley (Jamison Group)—NSF Graduate Research Fellowship

Yogesh Surendranath (Nocera Group)—Young Investigator Award, ACS Division of Inorganic Chemistry; NSF Graduate Research Fellowship; Solar Revolution Project Fellow, Chesonis Family Foundation

Jessica Tanuwidjaja (Jamison Group)—Amgen Summer Fellowship

Tom Teets (Nocera Group)—Fannie and John Hertz Foundation Graduate Fellowship, International Precious Metals Institute Sabin Metals Corporation Graduate Student Award

Sam Teitelbaum (Nelson Group)—Lester A. Wolfe Fellowship

Stephanie Teo (Nelson Group)— Natural Sciences and Engineering Research Council of Canada Postgraduate Scholarships (NSERC PGS-M), TA Award 2010

Y. Tao Uttamapinant (Ting Group)—C.P. Chu and Lai Summer Fellowship

Brian Walker (Bawendi Group)—NSF Graduate Fellowship, Most Outstanding Poster at the Fall 2010 Materials Research Society Meeting, invitation to join Sigma Xi

Darcy Wanger (Bawendi Group)—Hertz Foundation Fellowship, Ann and Paul Steinfeld Memorial Summer Graduate Fellowship

Thomas Willumstad (Danheiser Group)—David A. Johnson Summer Graduate Fellowship

Justin Wilson (Lippard Group)—International Precious Metals Institute Annual Student Award

Yan Zhou (Field Group)—C. P. Chu and Y. Lai Summer Fellowship

Doctoral and Master's Degree Recipients

Omar Ahmad, PhD (Movassaghi Group)

Glen Alliger, PhD (Nocera Group)

Trisha Andrew, PhD (Swager Group)

Alexander Barnes, PhD (Griffin Group)

Johnathan Cheng, PhD (O'Connor Group)

Tsz Yan Clement, PhD (Chan Group)

Christopher Clough, PhD (Cummins Group)

Eric Dane, PhD (Swager Group)

Loi Do, PhD (Lippard Group)

Jonathan Fischer, PhD (Ceyer Group)

Brett Fors, PhD (Buchwald Group)

Jennifer Fortune Schefiliti, PhD (Klibanov Group)

Scott Geyer, PhD (Bawendi Group)

Lesley-Ann Giddings, PhD (O'Connor Group)

Brenda Goguen, PhD (Imperiali Group)

Brian Hanna, PhD (Schrock Group)

Meredith Hartley, PhD (Imperiali Group)

Bryan Hsu, SM (Hammond Group)

Numpon Insin, PhD (Bawendi Group)

Wendy Iskenderian, PhD (Imperiali Group)

Yan Kung, PhD (Drennan Group)

Angelyn Larkin, PhD (Imperiali Group)

Yu-Tzu Li, PhD (Marzari Group)

Zhe Lu, PhD (Fu Group)

Pamela Lundin, PhD (Fu Group)

Smaranda Marinescu, PhD (Schrock Group)

Lisa Marshall, PhD (Bawendi Group)

Emily McLaurin, PhD (Nocera Group)

Christopher Morten, PhD (Jamison Group)

Rebecca Nicodemus, PhD (Tokmakoff Group)

Julia Robinson-Surry, PhD (Danheiser Group)

Weerawat Runguphan, PhD (O'Connor Group)

Kristin Schleicher, PhD (Jamison Group)

Taeho Shin, PhD (Nelson Group)

Jared Silvia, PhD (Cummins Group)

Sarah Slavoff, PhD (Ting Group) PhD

Woon Ju Song, PhD (Lippard Group)

Yogesh Surendranath PhD (Nocera Group)

Christine Tinberg, PhD (Lippard Group)

Daniel Turner, PhD (Nelson Group)

Brian Underwood, PhD (Jamison Group)

Brett Vanveller, PhD (Swager Group)

Brian Walker, PhD (Bawendi Group)

Lee-Ping Wang, PhD (Van Voorhis Group)

Cliff Wong, PhD (Bawendi Group)

Nancy Yerkes, PhD (O'Connor Group)

To view a slideshow of the Hooding Reception held on June 2, visit http://web.mit.edu/chemistry/www/hooding_commencement_2011/.

Griffin Herzfeld Reunion

On January 21–22, past and present graduate students, postdocs, and colleagues joined in a celebration of professors Robert G. Griffin and Judy Herzfeld. The theme of the reunion/symposium was "Four Decades @ the Magic Angle." An impressive lineup of speakers from the US, Europe, and Japan addressed the more than 120 people present, some of whom were Professor Herzfeld's colleagues and many of whom had worked on joint projects with the professors. The list of speakers is available at http://web.mit.edu/chemistry/www/cheminfo/griffin_herzfeld.pdf.

Research Highlights

Stephen L. Buchwald

During the past year the Buchwald group made significant progress on the development of new methods for organic synthesis. In particular, (1) it demonstrated that the combination of two ligands (one in the form of a precatalyst) provides a catalyst system with enhanced generality and versatility for Pd-catalyzed carbon-nitrogen bond-forming processes; (2) the group was able to develop catalysts that allow the conversion of aryl triflates to aryl halides; (3) the group derived a variety of processes for the formation of carbon-carbon and carbon-heteroatom bonds under flow conditions.

Arup K. Chakraborty

Professor Chakraborty's research has focused on three areas: (1) understanding fundamental questions in T cell signaling, (2) fundamental questions in how T-cells recognize a diverse and evolving world of microbes in a pathogen-specific fashion, and (3) confronting the challenge of how to design a vaccine against HIV. He has published papers in all three areas. Perhaps most notably, a paper that was published in *PNAS* identified regions of immunological vulnerability in HIV. This work brought together statistical physics with structural data and human clinical data. It suggests a new paradigm for design of vaccines against HIV and was highlighted with a story in the *Wall Street Journal* (and numerous other news outlets).

Rick L. Danheiser

Highlights during the past year include the development of a new method for the synthesis of pyridines, an important heterocyclic ring system. The new method involves a formal [2+2+2] cycloaddition strategy that proceeds via unusual cyano Diels-Alder and cyano ene reactions. Also reported in the past year was a method for the synthesis of polycyclic benzofused nitrogen heterocycles based on a tandem ynamide benzannulation/ring-closing metathesis strategy. This method was applied as a key step in a formal total synthesis of the antitumor agent (+)-FR900482.

Mircea Dinca

The Dinca group started a new research program focused on the synthesis and study of new microporous materials for applications in energy and catalysis. Highlights in our first year include the establishment of a new electrochemical method for the surface growth of crystalline microporous materials under a research project sponsored by BP through the MIT Energy Initiative.

Catherine L. Drennan

In collaboration with the laboratory of professor Ben Liu at the University of Texas at Austin, Catherine L. Drennan's group has published in the Journal of the American Chemical Society X-ray crystal structures depicting steps in the catalytic mechanism of an extraordinary antibiotic biosynthetic enzyme called hydroxypropylphosphonic acid epoxidase.

John M. Essigmann

The Essigmann laboratory reported in *PLoS One* in January that its compound, 5-aza, 5,6-dihydrodeoxycytidine, showed the anticipated mechanism of action in HIV patients treated in a Phase IIa clinical trial. This compound mimics a component of the innate immune system and may prove to be a new treatment for HIV/AIDS. The compound is the result of studies in the Essigmann laboratory on the mutagenic effects of DNA- and RNA-damaging agents.

Robert W. Field

A combined experiment-theory study of the acetylene S_1 electronic state provided the first observation of *cis*-conformer vibrational levels and illustration of the unique spectroscopic signature of *trans-cis* isomerization. Chirped pulse millimeter wave (CPmmW) spectroscopy was applied, for the first time, to observe superradiance and directly detect Rydberg-Rydberg transitions in an atomic beam, and to observe photolysis- and pyrolysis-product species/vibrational level populations. CPmmW spectroscopy was proven capable of measuring both transition moment and species populations in a single experiment, using photon echo to separate homogenous from inhomogeneous dephasing rates, and exploiting the free induction decay phase to distinguish upward from downward transitions and to sample propagation effects in an optically thick medium.

Stephen J. Lippard

A platinum (IV) cisplatin prodrug encapsulated into a nanoparticle equipped with an aptamer for targeted delivery to prostate cancer (Pca) was evaluated for toxicity and efficacy in vivo using a xenograft mouse model of Pca in mice. The conjugate was as effective as cisplatin at one-third the dose, and significantly less platinum accumulated in the kidneys, which are a major target site of cisplatin toxicity. In related work, the Lippard group employed a novel fluorescent sensor for mobile zinc (ZPP1) to detect and monitor the development of prostate cancer in a transgenic mouse model of prostate adenocarcinoma, using in vivo optical imaging correlated with biological fluid-based methods.

Mohammad Movassaghi

The Movassaghi research program continues to focus on the development of new strategies and technologies for complex molecule synthesis. The group has recently completed and reported the first general approach to the total synthesis of polythiodiketopiperazine alkaloids, including tetra-, hexa-, and octa-sulfurated dimeric diketopiperazines. The group also provided a uniform and biogenetically inspired synthesis of all (–)-agelastatin alkaloids, providing the shortest, most efficient, and largest scale synthesis of (–)-agelastatin A, the most potent member of this family of alkaloids. The hallmark of the 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 M. Nolan

The Nolan lab has discovered that the native disulfide array of human defensin 5, a cysteine-rich peptide produced by small intestinal Paneth cells, is essential for its antimicrobial activity against Gram-positive *Staphylococcus aureus,* whereas it is dispensable for killing of *Escherichia coli* (*E. coli*). In related work, the zinc binding ability of this peptide was investigated, and we discovered that metal-ion coordination confers protease resistance. In a separate thrust, a synthetic route to monofunctionalized enterobactin scaffolds was developed for use in an enterobactin-mediated cargo delivery strategy. Enterobactin, an iron chelator, is biosynthesized, exported, and imported by Gram-negative bacteria such as *E. coli* and Salmonella. A first-generation antibiotic-siderophore conjugate was prepared by linking ciprofloxacin to an enterobactin catechol.

Richard R. Schrock

The Schrock group has been developing new catalysts for the metathesis of olefins that are unusually reactive and selective for the formation of cis olefins. These new catalysts have been employed for the synthesis of complex natural products, new types of polymers, and chemicals from natural products such as seed oils. A second research project concerns the catalytic reduction of dinitrogen with protons and electrons. Current directions include the development of new molybdenum catalysts that contain a PNP "pincer" ligand.

JoAnne Stubbe

The Stubbe group discovered a new metallo-cofactor in ribonucleotide reductases (RNR) that contains a dimanganese cluster and a tyrosyl radical and is a homolog of the human RNR diferric-tyrosyl radical cofactor. The group also discovered distinct proteins involved in their biosynthesis. It is likely that all pathogenic organisms have the manganese version of this cofactor and inhibition of its biosynthetic pathway represents a new RNR target for antibacterials. The group has also shown that clofarabine, clinically used in the treatment of lymphoblastic leukemia, inhibits human RNR by causing one of its subunits to form a stable hexameric structure. Understanding the hexamerization process represents a new mechanism of targeting RNRs—already the successful target of three drugs used clinically.

Timothy M. Swager

The Swager group has made a number of major accomplishments in the chemistry of nanocarbon materials. These include the demonstration of artificial nose sensory devices capable of differentiating chemical vapors based on simple resistance changes, record low detection limits for the electrical detection of DNA, and a scalable technology for forming solutions of graphene layers. Additionally, the group has demonstrated a new molecular approach to tailoring materials interfaces in organic solar cells that produces greater efficiencies.

Andrei Tokmakoff

The Tokmakoff group published a report describing a new approach to distinguishing peptide conformers and characterizing structural disorder in peptides. This method,

which uses a combination of 2D IR spectroscopy of isotope-labeled peptides and computational modeling, sets the stage for structural characterization of intrinsically disordered proteins. Separately, the group performed experiments that conclusively demonstrate that hydrogen bonds in liquid water reorganize themselves through large angular jumps of an OH bond from one hydrogen-bond-accepting molecule to another.

Sylvia T. Ceyer
Department Head