

## Department of Chemistry

In the 2008–2009 academic year, the Chemistry Department continued its strong programs in undergraduate and graduate education. Currently there are 226 graduate students, 121 postdoctoral researchers, and 70 undergraduate chemistry majors. As of July 1, 2009, the Chemistry Department faculty will be comprised of 27 full-time faculty members, including one assistant, four associate, and 22 full professors, one of whom is an Institute Professor. There are 12 professors emeriti, including one Institute Professor. Timothy Jamison was promoted to full professor, and Alice Ting was promoted to associate professor with tenure. All of these promotions will take effect on July 1, 2009. In addition, two new assistant professors—Christian Degen and Elizabeth Nolan—will join the Chemistry faculty in 2009.

### Highlights

#### Dr. Christian L. Degen to Join Faculty

The aim of Christian Degen's research is the application of magnetic resonance imaging and spectroscopy at the extreme nanoscale in structural biology and for chemical surface identification. Such a capability will open new access to structural and chemical investigations of single biological entities, macromolecular assemblies, and nanostructured surfaces. Reaching these goals demands the development of novel, high-resolution magnetic sensing tools sensitive enough to access the nanometer regime.

Dr. Degen earned his PhD in physical chemistry under Professor Beat H. Meier at ETH Zurich, Switzerland. He will join the department in September 2009.

#### Dr. Elizabeth M. Nolan to Join Faculty

Elizabeth Nolan's research interests lie at the interface of chemistry and biology, with particular emphasis on the roles of metal ions in human physiology and disease. She is initiating an exciting new program at MIT that combines bioinorganic chemistry, in vitro enzymology, and cell biology.

Dr. Nolan, who will join the department on July 1, 2009, is an MIT alumna. She carried out her PhD studies in the group of professor Stephen J. Lippard.

#### Lippard to Receive Pauling Medal

The 2009 Pauling Medal will be awarded in November to professor Stephen J. Lippard, Arthur Amos Noyes professor of chemistry. The Linus Pauling Medal is given annually by the Oregon, Portland, and Puget Sound Sections of the American Chemical Society. The award recognizes outstanding contributions to chemistry meriting national and international recognition in the spirit of and in honor of Linus Pauling, a native of the Pacific Northwest. Professor Lippard will join a list of previous eminent recipients that includes the Chemistry Department's professor John S. Waugh, who received the award in 1984.

### **Movassaghi Receives Hoffmann-La Roche Award**

Mohammad Movassaghi, associate professor of chemistry, has been selected to receive the Hoffmann-La Roche Inc. (Roche) 2009 Excellence in Chemistry Award. Roche provides two such awards per year to outstanding young chemistry faculty members whom Roche anticipates will become world leaders in synthetic organic chemistry. The award is accompanied by an unrestricted research grant and a symposium.

### **Nocera Elected to the National Academy of Sciences**

Daniel G. Nocera, Henry Dreyfus professor of energy and professor of chemistry, has been elected to the National Academy of Sciences (NAS) in recognition of his distinguished and continuing achievements in original research. 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. Faculty members previously elected are professors Robert A. Alberty, Mounqi G. Bawendi, Stephen L. Buchwald, Klaus Biemann, Sylvia T. Ceyer, H. Gobind Khorana, Alexander M. Klibanov, Stephen J. Lippard, Richard R. Schrock, Dietmar Seyferth, Robert J. Silbey, JoAnne Stubbe, Timothy M. Swager, John S. Waugh, and Gerald N. Wogan.

### **Stubbe Receives the Prelog Medal**

The Swiss Federal Institute of Technology has selected JoAnne Stubbe, Novartis professor of chemistry and professor biology, as its 2009 recipient of the Prelog Medal. This medal is conferred annually to an individual identified by the institute as having made fundamental contributions in stereochemistry, broadly defined. Professor Stubbe is recognized for her pioneering work in chemical biology. The medal will be presented in Switzerland in October of this year.

### **Swager Receives the John Scott Award**

Professor Timothy M. Swager has been awarded the 2008 John Scott Award. This award recognizes men and women who have contributed in some outstanding way to the “comfort, welfare and happiness” of mankind. Swager was recognized “for his pioneering developments in the design, synthesis and construction of functional assemblies of supramolecular materials that recognize specific molecules. In creating new chemo sensors that are being used for the detection of concealed explosive materials, Professor Swager has greatly benefited mankind.” Professor Stubbe received the John Scott Award in 2005. Among the recipients of this award are Mme. Marie Curie, Thomas Edison, the Wright brothers, Edwin Land, Jonas Salk, Irving Langmuir, Glenn Seaborg, Frederick G. Banting, Guglielmo Marconi, John Bardeen, and Sir Joseph H. Thomson. In the past decade several recipients of this prestigious award have been Nobel Prize winners, including K. Barry Sharpless in 2001.

### **Ting Receives NIH Pioneer Award**

Alice Y. Ting, the Pfizer Laubach career development associate professor of chemistry, has been selected to receive a 2008 NIH Pioneer Award, which provides \$2.5 million in direct

costs over five years. NIH director Elias A. Zerhouni said, "Nothing is more important to me than stimulating and sustaining deep innovation, especially for early career investigators and despite challenging budgetary times, these highly creative researchers are tackling important scientific challenges with bold ideas and inventive technologies that promise to break through barriers and radically shift our understanding."

Professor Ting will use her award to develop new approaches to the study of endogenous proteins in living cells. The goal is to circumvent the problems associated with recombinant protein and transgene expression in cells and tissue to enable the study of endogenous proteins in their native form and context. Professor Ting is the second professor in the department to receive an NIH Pioneer Award since the inception of the program in 2004. Professor Arup Chakraborty received one in 2006.

### Former MIT Professor Roberts Receives a Chemical Breakthrough Award



*Left to right: Timothy M. Swager, John D. Roberts, Jeffrey Seaman and Frederick D. Greene. Photo by Elizabeth McGrath.*

John D. Roberts, institute professor emeritus of chemistry at the California Institute of Technology, received a Chemical Breakthrough Award from the American Chemical Society. The prestigious award marks his historic discovery, while a professor at MIT, of the "benzyne" mechanism in aromatic amination reactions. Roberts visited MIT to receive the award in December 2008, and present a fascinating lecture on his discovery.

### Other Major Faculty Awards and Honors for the 2009 Academic Year

Sylvia T. Ceyer, John C. Sheehan professor of chemistry and associate department head, was awarded an MIT Energy Initiative Seed Grant.

Arup K. Chakraborty, Robert T. Haslam professor of chemical engineering and professor of chemistry and biological engineering, was elected as a fellow of the American Association for the Advancement of Science. In addition, he gave the Raman Lectures.

Alan Davison, professor emeritus of chemistry, received the 2009 Georg de Hevesy Nuclear Medicine Pioneer Award (SNM).

John M. Deutch, Institute Professor and professor of chemistry, received the Gordon Y Billard Award for special service of outstanding merit performed for the Institute.

Robert W. Field, Haslam and Dewey professor of chemistry, was honored with the Earl M. Murman Award for Excellence in Undergraduate Advising and the 2009 Arthur L. Schawlow Prize in Laser Science (endowed by NEC Corporation).

Mohammad Movassaghi received several honors, including the 2009 Arthur C. Cope Scholar Award, the 2009 Bristol-Myers Squibb Unrestricted Grant in Synthetic Organic Chemistry, the 2009 Novartis Chemistry Lectureship Award, and the 2009 Society of Synthetic Organic Chemistry, Japan, Lectureship Award.

Daniel G. Nocera received the American Chemical Society Award in Inorganic Chemistry and the 2009 Intergovernmental Renewable Energy Organization's Science and Technology Award. In addition, he was chosen as one of *Time* Magazine's 100 most influential people in the world.

Dietmar Seyferth, Robert T. Haslam and Bradley Dewey professor emeritus of chemistry, was elected to the 2009 class of fellows of the American Chemical Society.

JoAnne Stubbe won the Nakanishi Prize.

Alice Y. Ting presented the 2008 Harvard University Department of Chemistry E. Bright Wilson Lecture and received the 2008 Buck Whitney Award.

### **Named Lectures**

The department welcomed many speakers who gave named lectures in AY2009:

Scott J. Miller, Yale University—Wyeth Lecture in Organic Chemistry

Zhenan Bao, Stanford University—Woodward Lectures in the Chemical Sciences

Chris Abell, University of Cambridge, UK—Novartis Lecture in Organic Chemistry

Steve Granick, University of Illinois—Dow Chemical Lecture/Physical Chemistry Seminar

Peter J. Sadler, Warwick University, UK—Davison Lecture

Amos B. Smith, University of Pennsylvania—George Büchi Lecture in Organic Chemistry

Guy Lloyd-Jones, University of Bristol, and Prashant Deshpande, Bristol-Myers Squibb—Bristol-Myers Squibb Lectures

Vern L. Schramm, Albert Einstein College of Medicine—T.Y. Shen Lectures

C. Dale Poulter, University of Utah—Merck-Pfister Lectures in Organic Chemistry

Dan Yang, University of Hong Kong—Eli Lilly Lecture in Organic Chemistry

Michael T. Crimmins, University of North Carolina at Chapel Hill, and Kevin Cusack, Abbott Bioresearch—Abbott Lecture in Organic Chemistry

Klaus Müllen, Max-Planck Institute—Dow Chemical Lecture/Organic Chemistry

David E. Cane, Brown University—Boehringer Ingelheim Lecture in Organic Chemistry

Herbert Roesky, University of Göttingen—A.D. Little Lecture in Inorganic Chemistry

## Department of Chemistry Visiting Committee

The department was pleased to welcome the Chemistry Department Visiting Committee on November 12–13, 2008. The committee, elected by the MIT Corporation, typically includes 17 members: five Corporation members assigned by the chairman of the Corporation (one of whom chairs the committee), six presidential nominees nominated by the president of MIT, and six alumni nominees. Operating as advisory groups to the Corporation, visiting committees afford the Corporation, senior administration, faculty, and students appraisal, advice, and insight on each academic department and on certain major activities at the Institute. Meetings provide faculty and students with opportunities to contribute to the governance of MIT, and they encourage stimulating and highly valued reviews. Important changes in departmental and Institute policy have resulted from visiting committee recommendations.



*Chemistry Department Visiting Committee, left to right: Dr. James W. Mitchell, Mr. Henri A. Termeer, Professor Laura L. Kiessling, Professor Charles P. Casey, Dr. Judith E. Selwyn, Mr. Frederick A. Middleton Jr., Professor Jacqueline K. Barton, Professor Laurie J. Butler, Dr. William F. Banholzer, Mr. Robert L. Blumberg (Chair), Dr. David A. Berry, Dr. Timothy J. Oyer, Dr. James J. Bishop, Dr. David L. Morse, Dr. James F. Kronauge.  
Photo by Elizabeth McGrath.*

## Undergraduate Education

The incredible energy and commitment the department's undergraduate and graduate students have for chemistry was evident throughout the past academic year. Whether talking to freshmen at open houses, giving tours to high school students, or embracing teaching assistant training boot camp and the responsibilities of teaching, students are sharing their excitement for the craft and are willing to do what it takes to inspire others.

## Class of 2009

The class of 2009 is an amazing group of young people. Incredibly diverse and already accomplished in their professional and personal fields of interest, many plan to attend graduate school in fields outside of chemistry. Of the 25 students who graduated, 64% are going on to graduate school, 24% are headed for medical school, and the remaining

12% plan to work before going on to medical or graduate school. These are typical figures for our students; what is atypical is that more than half (56%) are planning careers in fields such as materials science, civil engineering, oceanography, biology, and physics. When asked why, the majority said that they are excited to be able to bring their chemistry expertise to the frontiers of these other fields.

Some notable quotes from our senior survey follow:

I loved the Chemistry undergraduate program—it's given me a great foundation for understanding molecular interactions, and I think this foundation will be really helpful as I pursue research in structural biology.

I am planning to pursue a career in chemistry, and my great excitement for chemical sciences is certainly a product of my MIT education. ... Finally, I have to say that the teaching was wonderful in Chemistry; when I was choosing a major (deciding between computer science, biology, physics, and chemistry), I chose chemistry because the classes were so well taught (and the TAs were fabulous!).

I am planning to pursue a career in chemistry, and my great excitement for chemical sciences is certainly a product of my MIT education.

The 2009 Undergraduate Senior Recognition and Awards Banquet was held on Thursday, May 14, at the R&D Common Era in the Stata Center. The following awards were presented:

Alpha Chi Sigma Award for distinguished scholastic achievement, originality, and breadth of interest in chemistry—Annelise R. Beck, Stephen D. Fried, Veena Venkatachalam

Research Award for outstanding contributions in the area of research—Shanying Cui, Koyel Bhattacharyya, Kyrstin L. Fornace, Christopher J. Love, Thomas F. Martinez, Sarah J. Smith, Yunji Wu

Research and Teaching Award for outstanding contributions in the areas of research and teaching—Sarah C. Proehl

Frederick D. Greene Teaching Award for outstanding contributions in the area of teaching—Paul D. Boudreau

Merck Index Award for outstanding scholarship—Elise G. Liu, Tamara R. Litwin, Wen Hui Tan, Alexandra P. Tcaciuc

Hypercube Scholar Award in recognition of outstanding contribution to the advancement of computational chemistry—Jongjin B. Kim

Strem Award, in recognition of the best undergraduate research presentation at the UROP Symposium on January 29, 2009—Annelise R. Beck

American Chemical Society Analytical Chemistry Award for an outstanding analytical chemist (junior year)—Sidney E. Creutz

Barry M. Goldwater Award for Excellence in Education—Sidney E. Creutz (junior)

Sophomore Achievement Award for outstanding performance in academics, research, and service to the department—Jonathon T. Gunn

CRC Press Freshman Chemistry Achievement Award for outstanding academic achievement in chemistry—Daniel S. Levine

### **Graduate Student Teaching Assistants**

Once again, we were extremely fortunate to work with an outstanding team of teaching assistants (TAs). Engaged, enthusiastic, and willing to try new things, these TAs were outstanding in fulfilling their teaching requirement. Below is a small sample of the glowing remarks made by our undergraduates about their TAs:

“He did a wonderful job preparing us not only for tests, but also broadening our minds. I looked forward to every recitation and made sure never to miss one. His genial nature and approachability made me feel comfortable.”

“When chemistry seemed impossible, [my TA] was the light at the end of the tunnel.”

“[My TA] helped me view the material not as something that is going to overwhelm and crush me on exams, but as empowering techniques that will help me face new problems presented to me.”

This is the second group of TAs to go through our redesigned TA Training program, led by Dr. Sanjoy Mahajan from the MIT Teaching and Learning Lab. The student evaluation results are outstanding. On a scale of one to seven, 95% of our TAs received a 5.0 or better and 61% received a 6.0 or better. TAs do not receive these kinds of accolades from our students for just showing up. Indeed, MIT undergraduates have high expectations of their TAs, so to receive such scores says quite a lot about our graduate students' commitment to chemistry and to encouraging younger students.

### **Undergraduate Research Opportunities Program**

The Undergraduate Research Opportunities Program (UROP) remains the capstone experience for our undergraduates. With over 90% of our majors working in a research group (the majority in chemistry), they have the unique opportunity to conduct research alongside faculty, postdocs, and graduate students. In the recent senior survey, one student commented: “My UROP experience has defined my undergraduate education at MIT, and ‘very satisfied’ is certainly an understatement of how I feel towards the subject.”

Other comments about the UROP experience include:

...I enjoyed the research projects I worked on; I am proud of the diversity of skills that I obtained.

The opportunity to work in a lab doing actual experiments and interacting with graduate students is invaluable!!!

## UROP Publications

The following is a sample of recent publications by chemistry majors (in bold):

Bayro MJ, Huber M, Ramachandran R, **Davenport TC**, Meier BH, Ernst M and Griffin RG. Dipolar truncation in magic-angle spinning NMR recoupling experiments, *Journal of Chemical Physics* 2009, 130, 114506.

Field RW, Baraban JH, Lipoff SH, and **Beck AR**. Effective Hamiltonians, *Handbook of High Resolution Spectroscopies*, John Wiley and Sons (forthcoming).

Friedle S, Kodanko JJ, **Fornace KL**, and Lippard SJ. 9-Triptycenecarboxylate-bridged diiron(II) complexes: Capture of the paddlewheel geometric isomer, *Journal of Molecular Structure* 2008, 890(1):317–327.

**Lee BK**, Biscoe MR and Buchwald SL. Simple, efficient protocols for the Pd-Catalyzed cross-coupling reaction of aryl chlorides and dimethylamine, *Tetrahedron Letters* 2009, 50(26):3672–3674.

Rye PT, Delaney JC, **Netirojjanakul C**, Sun DX, Liu JZ, and Essigmann JM. Mismatch repair proteins collaborate with methyltransferases in the repair of O<sup>6</sup>-methylguanine, *DNA Repair* 2008, 7(2):170–176.

Steeves AH, Merer AJ, Bechtel HA, **Beck AR** and Field RW. Direct observation of the symmetric stretching modes of  $\tilde{A}_u^1$  acetylene by pulsed supersonic jet laser induced fluorescence, *Molecular Physics* 2008, 106(15):1867–1877.

**Tsui EY**, Müller P, Sadighi JP. Reactions of a stable monomeric gold(I) hydride complex, *Angewandte Chemie International Edition* 2008, 47(46):8937–8940.

Zhang X, **Hayes D**, **Smith SJ**, Friedle S, Lippard SJ. New Strategy for Quantifying Biological Zinc by a Modified Zinpyr Fluorescence Sensor, *Journal of the American Chemical Society* 2008, 130(47):15788–15789.

Zhang W, Sprafke JK, Ma M, **Tsui EY**, Sydlik SA, Rutledge GC, Swager TM. Modular functionalization of carbon nanotubes and fullerenes, *Journal of the American Chemical Society* 2009, 131(24):8446–8454.

Zhang W, Shaikh AU, **Tsui EY**, Swager TM. Cobalt porphyrin functionalized carbon nanotubes for oxygen reduction, *Chemistry of Materials* 2009, 21(14):3234–3241.

## Course 5 Events

The majors are active promoters of Course 5 and were on hand to talk with freshmen at the Academic Expo in August, the Majors Fair in November, and the Freshmen 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). In addition to the presentation during Family Weekend, the Magic Show also went to the International School of Boston and a community event in Cambridge. During Campus Preview Weekend in April, ClubChem gave tours of their UROP labs to over 60 prefreshman and their parents.



**Graduate Awards and Fellowships**

Omar Ahmad (Movassaghi Group)—Bristol-Myers Squibb Fellowship, Amgen Summer Fellowship, Wyeth Scholarship

Peter Bernhardt (O'Connor Group)—Morse Travel Grant, Daniel S. Kemp Summer Fellowship

Michelle M. Chang (Imperiali Group)—Praecis Presidential Fellowship

Jason Cox (Swager Group)—Corning Fellowship

Peter Curtin (Nocera Group)—National Defense Science and Engineering Graduate Fellowship

Brett Fors (Buchwald Group)—William Asbornsen Albert Memorial Fellowship; Roche Symposium: Excellence in Chemistry Award; Merck Summer Fellowship

Alexander Fox (Cummins Group)—Morse Travel Grant

Marcus Gibson (Drennan Group)—National Science Foundation Fellowship

Weslee Glenn (O'Connor Group)—Henry A. Hill Fellowship

Yan Kung (Drennan Group)—Morse Travel Grant

Angelyn Larkin (Imperiali Group)—Janette Houk Summer Fellowship, Wyeth Scholarship

Pamela Lundin (Fu Group)—Novartis Graduate Fellowship in Organic Chemistry for Women and Minorities, Morse Travel Grant

Smaranda Marinescu (Schrock Group)—2009 Bruker/MIT Poster Prize, Morse Travel Grant

Lisa Marshall (Bawendi Group)—David A. Johnson Summer Fellowship

Ellen Minnihhan (Stubbe Group)—Koch Fellowship from the Koch Institute for Integrative Cancer Research

Christopher Morten (Jamison Group)—Merck Summer Fellowship

Chunte Peng (Tokmakoff Group)—Presidential Fellowship

Krupa Ramasesha (Tokmakoff Group)—C.P. Chu and Y. Lai Summer Fellowship

Sean Roberts (Tokmakoff Group)—2009 Coblentz Society Student Award

Sarah Slavoff (Ting Group)—American Chemical Society Division of Organic Chemistry Fellowship, David A. Johnson Summer Fellowship

Georgily Teverovskiy (Buchwald Group)—National Defense Science and Engineering Graduate Fellowship

Ryan Todd (Lippard Group)—Strem Summer Fellowship

Meiliana Tjandra (Movassaghi Group)—Bristol-Myers Squibb Fellowship in Organic Chemistry, Roche Excellence in Chemistry Award

Darcy Wanger (Bawendi Group)—Hertz Fellowship

Thomas Willumstad (Danheiser Group)—George H. Büchi Summer Fellowship



*Hooding Ceremony, June 2009. Photo by Donna Coveney.*

## Research Highlights

### Arup Chakraborty

By bringing together statistical mechanical approaches with experimental tests (carried out by professor Art Weiss at the University of California, San Francisco), Arup Chakraborty's group discovered the molecular mechanism that enables the signaling machinery in T cells to be "on" or "off." This same machinery that allows digital signaling confers T cells short-term molecular memory of past encounters with antigen. These findings were published in *Cell*. They also shed light on a long-standing problem in immunology—T cell recognition of antigen is both exquisitely specific and degenerate. An analogy with spin-glass physics has allowed them to elucidate how a T cell repertoire with these characteristics is designed during development. These results were published in *PNAS*, and current research suggests that it may have deep implications for a particular aspect of the immune response to HIV. They also published other articles. Dr. Chakraborty led the MIT effort to establish the Ragon Institute of MGH, MIT, and Harvard.

### Christopher C. Cummins

Research in the laboratory of Christopher "Kit" Cummins in the past year has centered on early-metal mediated transformations of the group 15 elements. A breakthrough has been the synthesis of a new form of matter, manifested as a simple tetra-atomic molecule composed of a 1:3 ratio of arsenic and phosphorus atoms: the  $\text{AsP}_3$  molecule.  $\text{AsP}_3$  is a white crystalline substance that melts without decomposition at 72 °C, is easily purified by sublimation, and has ramifications for the synthesis of advanced electronic materials. Also advanced during the past year is a new paradigm for  $\text{CO}_2$  recycling that involves binding atop a metal nitride platform, rather than direct attachment to a metal center.

**Catherine L. Drennan**

In 2008, Catherine L. Drennan became an investigator with the Howard Hughes Medical Institute (HHMI). As the only professor recognized by the Howard Hughes Medical Institute for research (the investigator award) and teaching (named an HHMI Professor, or “Million-Dollar Professor”), Professor Drennan represents the teacher-scholar model of the American faculty member.

**John M. Essigmann**

John Essigmann’s group designed a bifunctional toxicant in which a DNA damaging agent was tethered to a ligand for the estrogen receptor. The molecule bound to DNA *in vivo* and then functionally displaced the endogenous estrogen receptor from its normal sites of action. The compound was sevenfold more persistent in ovarian cancer cells that expressed normal levels of the receptor, as compared to the same cells in which RNA interference was used to suppress the expression of the receptor. In other work, an antiviral agent designed initially in his laboratory has successfully reached Phase IIa clinical trials; this molecule ablates viral populations by forcing the virus to exceed its error catastrophe limit.

**Robert W. Field**

In collaboration with professor Anthony Merer, of the University of British Columbia, all of the vibrational levels of the acetylene  $S_1$  state, up to the top of the *trans-cis* isomerization barrier, were observed by Dr. Adam Steeves, including some belonging to the *cis*-bent conformer, which despite 50 years of intense spectroscopic study, had escaped detection. Brooks Pate’s revolutionary chirped pulse millimeter-wave scheme was shown, by Barratt Park and Dr. Kirill Kuyanov, to be  $10^3$  times more sensitive than standard bolometer detection schemes.

**Timothy F. Jamison**

The Jamison group’s research focuses on the discovery and implementation of new reactions for organic synthesis. Many of the chemical reactions synthesize structural motifs found in natural molecules and pharmaceuticals. The group is also inventing reactions that convert the greenhouse gas carbon dioxide ( $CO_2$ ) into useful materials. Two other active areas are “green chemistry” and continuous-flow chemistry for pharmaceutical manufacturing.

**Barbara Imperiali**

Ongoing research focuses on protein glycosylation in selected prokaryotic pathogens, such as *Campylobacter jejuni* and *Neisseria meningitides* with the goal of understanding the roles of cell surface carbohydrates in human infectious diseases. In particular, an emphasis is being placed on investigating the specific function of unusual and highly modified carbohydrates in bacterial glycoprotein conjugates. Research also focuses on the application of innovative chemical tools for the study of biological systems. In particular, methods for sensitive and selective methods for diagnosing the dynamic fluctuations of enzyme activities, such as kinases, and protein/protein interactions are being developed for studies of cell migration, cell cycle control, and the regulation of synaptic plasticity.

**Stephen J. Lippard**

A fluorescent sensor was devised that can quantitate absolute concentrations of mobile zinc, which mediates a host of biological functions ranging from neurotransmission to insulin release from the pancreas. A novel strategy was reported for generating DNA plasmids containing pre-defined platinum anticancer drug adducts for determining their role in disrupting transcription and other processes in live cells. A critical peroxo intermediate was identified in the enzyme that catalytically converts toluene to cresol at a non-heme diiron center.

**Mohammad Movassaghi**

The Movassaghi group's research program continues to focus on the development of new strategies and technologies for complex molecule synthesis. They have completed and reported the first total synthesis of 11,11'-dideoxyverticillin A, a complex epidithiodiketopiperazine alkaloid, and also the first total synthesis of a class II galbulimima alkaloid, representing the first such total synthesis of these compounds in 40 years since their initial isolation from nature. 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. Additionally, the group has continued to develop new and practical methodologies for the rapid synthesis of important azaheterocycles that are ubiquitous in natural products, pharmaceuticals, and functional materials.

**Sarah E. O'Connor**

Professor O'Connor's research focuses on elucidating and reengineering the biosynthetic pathway of terpene indole alkaloids, a complex metabolic pathway responsible for the production of hundreds of pharmaceutically important alkaloid natural products. The O'Connor group has successfully developed a variety of strategies to alter medicinal plant metabolism to produce novel alkaloid natural products.

**Robert J. Silbey**

Professor Silbey, in collaboration with students and colleagues, published a number of research papers on energy transfer processes, especially those associated with chlorophyll complexes in photosynthetic organisms.

**Joanne Stubbe**

The Stubbe lab has developed Gemzar, a drug currently used in the treatment of advanced pancreatic cancer and non-small cell lung carcinoma. The phosphorylated metabolites of this nucleoside interfere with many steps in nucleotide metabolism including ribonucleotide reductases (RNR). This past year they have demonstrated that the diphosphate of gemzar is a substoichiometric mechanism-based inhibitor of both human RNRs. While this compound acts like the classical mechanism-based inhibitors elucidated by the efforts of their lab, the added twist is that the subunits of the enzyme become tightly associated during inactivation. This novel mechanism likely plays a key role in its therapeutic efficacy.

**Timothy M. Swager**

The Swager research group continues to focus on transformational chemical and biological sensors for security, environment monitoring, and health care. Highlights from the past year include the development of carbon nanotube systems with unprecedented selectivity for different aromatic compounds. In the area of energy research, this group has recently developed electrocatalytic materials based upon cobalt complexes covalently linked to carbon nanotubes, new luminescent solar concentrator materials, and organic photovoltaic systems.

**Alice Y. Ting**

Alice Ting's lab engineers reporters for live cell imaging. They have developed highly specific, minimally invasive reporters for imaging of protein trafficking and protein-protein interactions, at both the ensemble and single molecule levels in living cells. Over the past year, her lab has applied these novel reporters to uncover new biological functions of the synaptic adhesion proteins neuroligin and neuroligin.

**Andrei Tokmakoff**

The Tokmakoff group studies time-dependent changes of molecular structure in chemical reactions and biophysical processes by developing advanced time-resolved spectroscopy. They are using two-dimensional infrared spectroscopy and molecular dynamics simulations to study the mechanism by which a proton is transported along hydrogen bonding networks in water. They also have studied an array of biophysical dynamics problems, including the mechanism of insulin dimer formation and the conformation of peptides in solution.

**Troy Van Voorhis**

Research in the Van Voorhis group has focused on several major topics in the past year: modeling reaction barriers and excited states using density functional theory, constructing QM/MM models of organic semiconductor electronic structure, describing conductance in metal-molecule-metal junctions, and developing techniques for the description of intermolecular interactions.

**Timothy M. Swager, PhD**  
**Department Head**  
**Professor of Chemistry**

*More information about the Department of Chemistry can be found at <http://web.mit.edu/chemistry/www/>.*