Department of Chemistry

In academic year 2014–2015, the Department of Chemistry had 30 full-time faculty members (two dual faculty appointments: one with Biological Engineering and one with the Institute of Medical Engineering and Science): 8.5 assistant, one associate, and 20.5 full professors. Four faculty members (Catherine Drennan, Alexander Klibanov, and JoAnne Stubbe) have secondary appointments in Biology and Biological Engineering. Four additional faculty members (Arup Chakraborty, Barbara Imperiali, Susan Solomon, and Steven Tannenbaum) have secondary appointments in Chemistry. In addition to research in biological, environmental, inorganic, organic, physical, and materials and nanoscience chemistry, the department continued its strong programs in undergraduate and graduate education with 240 graduate students, 135 postdoctoral researchers, and 57 undergraduate chemistry majors.

Effective July 1, 2015, Professor Timothy Jamison will assume the position of head of the department. He will inherit a strong and vibrant department from his predecessor, Professor Sylvia Ceyer, who, over the past five years, worked with exceptional dedication to bring the renovation of the chemistry space in Building 2 to completion, designed the new undergraduate teaching laboratory to be located in the MIT.nano building, initiated the Committee on Graduate Student Climate, and hired many of the department's outstanding junior faculty as well as one tenured colleague. Professor Mei Hong joined the department as professor of chemistry effective July 1, 2014. Professor Mircea Dincă will assume the rank of associate professor without tenure. Professor Catherine Drennan will transfer to the Department of Biology, but retains a secondary appointment in Chemistry.

Professor Alexander K. Shalek was appointed to the Hermann L. F. von Helmholtz Career Development Professorship effective July 1, 2014 for a period of two years. Professors Keith A. Nelson and Troy Van Voorhis were named Robert T. Haslam and Bradley Dewey Professors of Chemistry, effective January 1, 2015. Professor Christopher C. Cummins will assume the Henry Dreyfus Professor in Chemistry Chair effective July 1, 2015. Professors Jeremiah A. Johnson and Jeffrey Van Humbeck became the holders of Firmenich Career Development Professorships for a three-year term effective January 1, 2015.

Faculty Awards and Honors

In January 2015, The BBVA (Banco Bilbao Vizcaya Argentaria) Foundation Frontiers of Knowledge Award in Basic Sciences was awarded to Professor Stephen L. Buchwald, the Camille Dreyfus Professor of Chemistry, "for the development of catalytic routes based on palladium and copper to construct carbon-nitrogen and carbon-carbon bonds," an advance with great impact on the "efficient synthesis of modern pharmaceuticals and compounds for agricultural use." In December 2014, Professor Buchwald was also awarded the University College Dublin Ulysses Medal, the highest honor that University College Dublin can bestow. The award recognizes his outstanding global contribution to the field of chemistry.

In February 2015, Sylvia Ceyer, the J. C. Sheehan Professor of Chemistry and head of the department, was elected to the Governing Council of the National Academy of Sciences for a three-year term commencing July 1, 2015. She was also awarded a Professor Amar G. Bose Research Grant, named for a longtime member of the MIT faculty and the founder of Bose Corporation. Bose Grants fund high-risk—but potentially high-reward—projects that would be considered impossible to fund through conventional sources, offering up to $500,000 over three years.

In August 2014, Professor Rick L. Danheiser, the A. C. Cope Professor of Chemistry, was awarded the 2014 Teaching Prize for Graduate Education by the MIT School of Science.

In March 2015, Catherine L. Drennan, professor of chemistry and biology and a Howard Hughes Medical Institute professor and investigator, was named a 2015 MacVicar Fellow for exceptional undergraduate teaching, mentoring, and educational innovation.

In August 2014, Jeremiah Johnson received a National Science Foundation (NSF) Early Career Development Award.

In April 2015, a symposium titled "Metals for Life" honored Professor Stephen J. Lippard, the Arthur Amos Noyes Professor of Chemistry at MIT and the 2015 recipient of the Benjamin Franklin Medal in Chemistry for his pioneering research and wide-ranging contributions to the field of bioinorganic chemistry.

In August 2014, Professor Elizabeth M. Nolan received a NSF Early Career Development Award.

In March 2015, Professor Bradley L. Pentelute, the Pfizer-Laubach Career Development Assistant Professor, was awarded a 2015 Sloan Research Fellowship. 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. In August 2014, Professor Pentelute received a NSF Early Career Development Award.

In August 2014, Professor Richard R. Schrock, the F. G. Keyes Professor of Chemistry, was honored with the 2014 Paracelsus Prize. The Paracelsus Prize is the highest award given by the Swiss Chemical Society and is awarded biennially to an internationally outstanding scientist for his or her lifetime achievements in chemical research.

In April 2015, Alexander Shalek was awarded a 2015 Searle Scholars Award. The Searle Scholars Program supports research of outstanding individuals who have recently begun their appointment at the assistant professor level.

The US Department of Energy announced in June 2015 that Professor Yogesh Surendranath would receive a 2015 Early Career Research Program award. The program supports the development of individual research programs of outstanding scientists early in their careers. In November 2014, The Camille and Henry Dreyfus Foundation selected Professor Surendranath as an award recipient to the Postdoctoral Program in Environmental Chemistry.

In July 2014, Professor Timothy M. Swager, the John D. MacArthur Professor of Chemistry, was selected to receive a Humboldt Research Award. The Alexander von Humboldt Foundation grants this award in recognition of a researcher's entire academic achievements to date, and whose fundamental discoveries, new theories, or insights have had a significant impact on their own discipline and who are expected to continue producing cutting-edge achievements in the future.

Development News

Dr. Scott Rocklage, PhD '82 (Chemistry), and his wife Patty pledged $250,000 to assist with the costs associated with the renovation of the nanochemistry and nanotechnology lab space in Building 2. Dr. Rocklage carried out his PhD studies in the Department of Chemistry under Nobel Prize winner in Chemistry, Professor Richard R. Schrock.

Dr. Judith E. Selwyn, PhD '71 (Chemistry), and her husband, Dr. Lee L. Selwyn, MIT PhD '69 (Management), as Trustees of the Lee L. and Judith E. Selwyn Foundation, pledged $250,000 to support the new undergraduate teaching laboratories that will be housed in the MIT.nano building due to be completed in 2018. In November 2014, the Selwyns hosted a dinner for alumni and faculty in their home. Judy is taking a leadership role in helping to raise funds for the MIT.nano project. Sylvia Ceyer gave a tribute to Judy and Lee for their hospitality and their generous commitment, and invited others to follow the Selwyns' lead.

Dr. Gregory C. Fu, SB '85, (Chemistry) created an endowed fund of $100,000 in the Department of Chemistry in honor of his Undergraduate Research Opportunities Program (UROP) adviser, Professor K. Barry Sharpless. The fund will be used to provide several annual travel grants for graduate students (with a preference for those studying organic chemistry) to travel to national meetings and conferences.

The Department is extremely grateful to the following alumni and friends for their support by way of summer graduate student support and, in a couple of cases, half-yearly support, as well as travel grants for students to attend national and international meetings and conferences throughout the year:

Dr. Ping S. Chu

Dr. Michael E. Strem

Professor Alan Davison

Mrs. Merece Johnson

Dr. David L. Morse

Dr. Daniel C. Harris and his wife, Mrs. Sally L. Harris

Ms. Judith E. Hughes and her sister, Ms. Mary Lee Berger-Hughes

Dr. Kin Chun T. Luk and his wife, Mrs. Yuen-Kwan Luk

Professor Jeffrey I. Steinfeld

Dr. and Mrs. T-Y Shen

Dr. Gregory C. Fu

Thanks to the generosity of two long-standing and thoughtful anonymous supporters, the Department of Chemistry hosted a springtime celebration on May 18, 2014.

More than 60 alumni, friends, and faculty gathered in the winter garden of MIT's Media Lab. Guests enjoyed not only spectacular views of the Charles River and Back Bay, but also conversation and presentations focused on the department's educational and research accomplishments, future plans, goals, and special projects. A video entitled "Just The Right Chemistry" was produced especially for the event.

Dr. Judith E. Selwyn, PhD '71 on left chats with Dr. John Dolhun, PhD '73 and his wife Katy.

Named Lectures

The department welcomed the following named speakers during fall 2014 and spring 2015:

- Merck-Banyu Lecture in Organic Chemistry: Daisuke Uraguchi, Nagoya University
- Novartis Lectures in Organic Chemistry: Antonio Echavarren, Institute of Chemical Research of Catalonia, and Lawrence G. Hamann, Novartis
- Davison Lectures in Inorganic Chemistry: Clark Landis, University of Wisconsin-Madison
- Georgia-Pacific Lecture in Organic Chemistry: Andrew I. Cooper, University of Liverpool
- Pfizer-MIT Lecture in Organic Chemistry: Benjamin List, Max-Planck-Institut für Kohlenforschung
- Buchi Lectures in Organic Chemistry: Peter Seeberger, Max-Planck-Gesellschaft

- TY Shen Lectures in Biological Chemistry: Donald Hilvert, Eidgenössische Technische Hochschule Zürich (ETH Zurich)
- Merck-Pfister Lectures in Organic Chemistry: Eric Anslyn, University of Texas
- Bristol-Myers Squibb Lectures in Organic Chemistry: Tomislav Rovis, Colorado State University, and John E. Macor, Bristol-Myers Squibb
- Merck-Pfister Lecture in Organic Chemistry: Kyoko Nozaki, University of Tokyo

Serving the Institute

The Department of Chemistry provides key educational service to the Institute. During the 2014–2015 academic year, the department taught 1,605 MIT undergraduate students in the areas of biochemistry, inorganic, organic, and physical chemistry. The department was also home for 61 UROP (Undergraduate Research Opportunities Program) students, providing important mentoring relationships for students from a number of departments, including chemistry, biology, mathematics, physics, chemical engineering, biological engineering, electrical engineering, and materials science.

Chemistry Majors

We continue to consistently attract a very talented group of undergraduates to Course 5, with a total of 57 majors across three years. This year, 20 students received SB degrees in Chemistry. In exit surveys, we found that 46% of the Class of 2015 was bound for graduate school and 8% planned to attend medical school; 31% decided to seek employment.

Undergraduate Research Opportunities Program

The UROP experience continues to be an annual highlight 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, postdocs, and graduate students.

Chemistry Teaching Assistants

Our graduate student TA's are some of the best at MIT. This year, students gave 74% of our TA's a 6.0 or higher on a 7.0 scale. Of those in this percentile, 47% received a 6.5 or higher.

L to R: Colleen Gabel, Jennifer Plotkin, Ethan Klein, Daniel Zhang, Martin McLaughlin, Jakob Dahl, Hansol Kang, Khetpakorn Chakarawet, Kevin Erazo, Nevin Daniel, Tabitha Miller, and Sarah Toledano. Not pictured: Bara Badwan, Alexandra Hall, Kayvon Pedram, Patreece Suen, Rebecca Taylor, Joshua Vagts, and Kevin Yan. Photo: Alison Martin.

Undergraduate Achievement Awards

Undergraduate Awards were given out at the 2015 Undergraduate Senior Recognition and Awards Banquet on May 14, 2015.

Freshmen Chemistry Achievement Award
For outstanding academic achievement in chemistry
Puwanat Sangkhapreecha

Outstanding Sophomore Achievement Award
For outstanding achievement in academics, research, and service to the Department of Chemistry
James Deng
Tomohiro Soejima

ACS Analytical Chemistry Award
For outstanding achievement by a junior in experimental chemistry
Julia Page

Outstanding UROP Presentation Award
For outstanding undergraduate research and in recognition of the best presentations at the 2015 Chemistry UROP Symposium
Khetpakorn Chakarawet
Hope Flaxman
Martin McLaughlin

Alpha Chi Sigma Award
For outstanding achievement in scholarship, research, and service to the Department of Chemistry
Khetpakorn Chakarawet
Martin McLaughlin

Research Award
For outstanding contributions in the area of research
Hansol Kang
Rebecca Taylor
Daniel Zhang

Frederick D. Greene Teaching Award
For outstanding contributions in the area of teaching
Ethan Klein

ACS Inorganic Chemistry Award
For excellence in inorganic chemistry
Khetpakorn Chakarawet

Merck Index Award
For outstanding scholarship
Colleen Gabel
Kayvon Pedram
Jennifer Plotkin
Rebecca Taylor

Service Award
For significant contributions in the area of service to the Department of Chemistry
Jakob Dahl
Kevin Erazo
Kayvon Pedram
Jennifer Plotkin
Daniel Zhang

Hypercube Scholar Award
For outstanding contribution to the advancement of computers in teaching
Jakob Dahl

Special Recognition

Association of MIT Alumnae (AMITA) Award Nominee
Rebecca Taylor

2015 ASC Certification in Biochemistry
Hansol Kang
Daniel Zhang

Phi Beta Kappa 2015 Inductees
Khetpakorn Chakarawet
Colleen Gabel
Martin McLaughlin
Kayvon Pedram
Jennifer Plotkin
Rebecca Taylor

Teaching Assistant Awards

Laura Avena
Sophie Bertram
Ryan Duncan
Trevor Erickson
Anmol Gulati
Jennifer Hu
Alexander Hull
Bryan Ingoglia
Megan Jackson
Yivan Jiang
Liam Kelly
Soyoung Kim
Kathleen Martin
Chase Olsson
Anthony Quartararo
Christopher Richardson
Nathan Ricke
Hyowon Seo
Amanda Wicker

The Department of Chemistry Award for Continued Excellence in Teaching went to Allena Goren. This prestigious award recognizes sustained service and excellence in teaching within the department and is presented to graduate students who have taught for at least three terms and have previously won the award.

Excerpts from TA Evaluations

> "[NAME] is an extremely dedicated TA. He is an amazing teacher, he knows exactly what he is talking about and is great at presenting hard to understand concepts in logical ways. He is quick to reply to emails, helped me learn at every review session, and really made the material much more interesting than it already was. I hope he keeps teaching, because he really makes a positive difference."
> "[NAME] was an incredibly fantastic TA. Not only did he truly care about his students and always went the extra mile to help them learn, but his palpable enthusiasm for the subject was truly contagious. His always took great care to make his explanations in recitation clear and complete, and he provided very helpful feedback on problem sets. [NAME] embodies everything that a great TA should strive to be."

"[NAME] has to be, by far, one of my best TAs since coming to MIT. He always makes time to meet with his students and really cares about their progress and learning. I feel very lucky to have had him as my TA."
"Went above and beyond to help when I was struggling. Didn't hesitate to reach out and try to do everything possible to make the class better."
"[NAME] was just amazing. She is extremely dedicated and knowledgeable. She was always available to meet, including when help was needed for concepts and analysis. She is a great teacher, and has done a wonderful job at making the material interesting and exciting. Thank you!"
"The best, most passionate TA ever! She got to know us really well and went out of her way to support us. She really loves chemistry and is extremely knowledgeable. She cares so much about being a TA and being as helpful as possible, which was so amazing!"
"[NAME] was very helpful when teaching and was available to meet outside of recitation and lecture. He was also friendly, which made attending recitation more appealing for this class. Lastly, his exam review sessions were legendary! He covered nearly all the material that had been lectured on in the previous few weeks, and it finally stuck."
"[NAME] was very timely and transparent with grading, explained concepts thoroughly, and most importantly, was always very willing to answer questions."
"Always helpful with lab questions and asked thought-provoking questions to get us to think beyond the scope of the lab."
"[NAME] was a fantastic TA. She was very thorough in her prelab lecture in order for us to understand the importance of the details of the experiment. I think she would be a fantastic lecturer. She encouraged students to do their best in labs and was always ready to help and advise whenever needed. I feel very lucky to have had her as a TA this semester."

Doctoral and Master's Degree Recipients

Professor Sylvia T. Ceyer with Christopher Leon.

Date	Name	Degree	Group
Sep-14	Armbrust, Kurt	PHD	Jamison
Sep-14	Choi, Junwon	PHD	Fu
Sep-14	Davis, Nicole	PHD	Hammond
Sep-14	Hsu, Bryan	PHD	Hammond
Sep-14	Lee, Sarah	PHD	Fu
Sep-14	Liu, Harris	SM	Klibanov
Sep-14	Lu, Jingnan	PHD	Sinskey
Sep-14	Victor, Eric	PHD	Lippard
Sep-14	Wei, He	PHD	Bawendi
Sep-14	Xie, Wanqin	SM	Van Voorhis
Sep-14	Zhou, Yan	PHD	Field
Feb-15	Adams, Timothy	PHD	Movassaghi
Feb-15	Chang, Michelle	PHD	Imperiali
Feb-15	Heathcote, Leigh	SM	Bawendi
Feb-15	Jensen, Russell	PHD	Bawendi
Feb-15	Mandal, Aritra	PHD	Tokmakoff
Feb-15	Park, Barratt	PHD	Field
Feb-15	Slavin, Orly	PHD	Stultz
Feb-15	Sowers, Molly	SM	Johnson
Feb-15	Standley, Eric	PHD	Jamison
Feb-15	Velian, Alexandra	PHD	Cummins
Feb-15	Vinogradova, Ekaterina	PHD	Buchwald
Feb-15	Zhu, Rong	PHD	Buchwald
Jun-15	Axtell, Jonathan	PHD	Shrock
Jun-15	Brophy, Megan	PHD	Nolan
Jun-15	Brozek, Carl	PHD	Dinca
Jun-15	Bruno, Nicholas	PHD	Buchwald
Jun-15	Eliason, Jeffrey	PHD	Nelson
Jun-15	Frazier, Kelvin	PHD	Swager
Jun-15	Funk, Michael	PHD	Drennan
Jun-15	Gibson, Marcus	PHD	Drennan
Jun-15	Goods, John	PHD	Swager
Jun-15	Han, Grace	PHD	Swager
Jun-15	Hontz, Eric	PHD	Van Voorhis
Jun-15	Horning, Andrew	PHD	Tidor
Jun-15	Jost, Marco	PHD	Drennan
Jun-15	Leon, Christopher	PHD	Ceyer

Date	Name	Degree	Group
Jun-15	Liang, Alexandria	PHD	Lippard
Jun-15	Manke, Kara	PHD	Nelson
Jun-15	Martell, Jeffrey	PHD	Ting
Jun-15	Milner, Phillip	PHD	Buchwald
Jun-15	Niljianskul, Nootaree	PHD	Buchwald
Jun-15	Weis, Jonathan	PHD	Swager
Jun-15	Ziegler, Daniel	PHD	Fu

Faculty Research Highlights

Stephen L. Buchwald

The Buchwald research group achieved significant advancements in the areas of carbon-carbon and carbon-heteroatom bond formations. It has found highly selective catalytic systems for the enantiomerically pure (single-handed) form of a wide variety of amines from extremely simple (alkene) precursors. In collaboration with Professor Pentelute's lab, the group also developed new techniques for the functionalization of complex biomolecules. Additionally, by studying and understanding the mechanisms of the reactions, members have been able to design new ligands to render even the most difficult cross-couplings accessible. These methods are general, practical, and can readily be applied to the synthesis of pharmaceutical agents, sensor or biologically relevant compounds and materials.

Sylvia T. Ceyer

The Ceyer group has continued its study of the dissolution of hydrogen into the bulk of Ni that is enabled by the formation of an Au-Ni alloy on the surface. This alloy is an excellent model for the Raney Ni alloy, used commercially in all heterogeneous catalytic hydrogenation reactions. The Ceyer group has also discovered Ni spin excitations in high-resolution electron energy loss scattering from the Au-Ni surface alloy. The physical mechanism for the appearance of spin excitations in the presence of Au is under investigation.

Rick L. Danheiser

One of the main accomplishments of the Danheiser laboratory during the past year was the synthesis of the first highly strained cyclic ynamide. The structure of this remarkable molecule incorporates an extremely strained carbon-carbon triple bond within a six-membered heterocyclic ring. The Danheiser lab has demonstrated that this molecule is a useful building block, participating in a very selective fashion in a number of useful synthetic transformations.

Mircea Dincă

The Dincă group in the Department of Chemistry advanced the science of porous conductive materials and showed that materials that have high surface area can also conduct electricity. This opens up new applications in energy storage such as batteries

and super-capacitors, and provides a new set of materials for investigating exotic electronic phenomena in solid-state physics. In a parallel line of research, the Dincă group also published a definitive review on how to produce new porous materials containing a variety of metal ions, and are now demonstrating their utility in supported heterogeneous catalysis, primarily in the transformation of small hydrocarbon molecules from the natural gas industry.

Catherine L. Drennan

Metalloproteins, which account for up to 50% of all enzymes, cannot function without corresponding metallochaperones that deliver the appropriate cofactors. Understanding this delivery process has been hindered by a lack of structural information depicting how metallochaperones contact their target enzyme. To address this deficiency, the Drennan lab determined the first crystal structures of a G-protein metallochaperone associated with a target protein.

John M. Essigmann

The principal spontaneous and oxidative stress-induced genetic change involves a C:G base pair in DNA changing to a T:A base pair. The second most frequent genetic change in aerobic organisms is a G:C pair changing a T:A. Some years ago the Essigmann group discovered that the G:C to T:A change was owed to the pairing of an oxidized form of guanine—7,8-dihydro-8-oxoguanine—with adenine during replication. This year they discovered that another common oxidative stress lesion, 5-chlorocytosine, is a likely contributor to the C:G to T:A changes, which dominate the mutational spectrum of aerobes and are particularly prevalent after bouts of inflammation. Their hypothesis is that the activation of neutrophils and other immune system cells causes production of hypochlorous acid, which chlorinates cytosines, leading the formation of the mutagenic lesion. This pathway may trigger the development of inflammation-induced cancers.

Robert W. Field

In the spectra of acetylene and [H,C,N], the Field lab identifies the universal signature of the structures of isomerization transition states. The combination of two revolutionary technologies (chirped pulse millimeter wave spectroscopy and a buffer gas cooled ablation source) generates spectroscopic information one million times faster than the previous best methods. It provides a powerful way to separately characterize each physical interaction mechanism between an electron and a cation. In collaboration with the Cummins group, the Field lab demonstrates a unique fusion of chemical synthesis of highly reactive molecules with high-resolution spectroscopy.

Timothy F. Jamison

In collaboration with Klavs F. Jensen and Allan Myerson (both in the Chemical Engineering Department), the Jamison 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 include disaster relief, developing nations, green manufacturing, and orphan/neglected diseases. The group also developed several other continuous flow methods for the synthesis and purification

of important classes of molecules and developed several families of new nickel complexes and reactions that they expect to find broad utility in synthesis.

Jeremiah A. Johnson

The Johnson group developed a robust technique for making polymers with precise structure that could be used as new drug delivery systems or biodegradable materials. They also designed a new type of polymeric material that spontaneously assembles in the presence of certain metals. These materials could find applications in removal of organic and heavy metal pollutants from water.

Stephen J. Lippard

An osmium compound was discovered that selectively kills breast cancer stem cells, thought to be responsible for tumor recurrence and metathesis, by dual action at both the nucleus and the endoplasmic reticulum. A far-red emitting probe for unambiguous detection of mobile zinc in acidic vesicles and deep tissue was synthesized, and sensors of this kind as well as fast zinc chelating agents were applied to discover that mobile zinc modulates receptors in the brain responsible for hearing, smell, and vision. Platinum pro-drugs were designed to bind non-covalently to human serum albumin for drug delivery. Blend Therapeutics, co-founded by Lippard, used mechanistic information about platinum anticancer drugs provided by work in the Lippard lab to devise a novel clinical cisplatin pro-drug scheduled to begin a Phase I clinical trial toward the end of 2015.

Mohammad Movassaghi

The Movassaghi lab continues to focus on the development of new strategies and technologies for complex molecule synthesis. The lab recently provided an account of its biogenetically inspired total synthesis of epidithiodiketopiperazines and related alkaloids, a family of alkaloids with potent anticancer activity. The lab also reported the direct observations of intermediates involved in their electrophilic activation and spirocyclization of tryptamine based amide and application of this strategy to the concise and enantioselective total synthesis of (−)-mehranine, (−)-methylenebismehranine, and related aspidosperma alkaloids. The hallmark of the lab's syntheses is their unparalleled efficiency and high level of stereochemical control in complex settings, taking full advantage of the inherent chemistry of plausible biosynthetic intermediates.

Elizabeth M. Nolan

The Nolan Lab established that the antimicrobial protein human calprotectin sequesters ferrous iron by using a hexahistidine coordination motif that is unprecedented for non-heme iron proteins. In studies of the cysteine-rich host-defense peptide HD6, which has been proposed to block bacterial invasion in the human gut by self-assembling into "nanonets" that entrap bacteria, the laboratory discovered that this peptide inhibits biofilm formation by the opportunistic human pathogen Candida albicans. This work broadens the innate immune functions of HD6 to include defense against fungi, and suggests that HD6 protects the intestinal epithelium against C. albicans. In collaboration with the Raffatellu Lab at UC Irvine School of Medicine, a siderophore-based

vaccination has been achieved in a mouse model and this immunization affords mucosal antibodies that capture enterobactin and salmochelins as well as protection against the gastrointestinal pathogen Salmonella enterica serovar Typhimurium.

Bradley L. Pentelute

During this past year, the Pentelute lab continued to improve methods for the rapid manufacturing of peptide drugs, delivery of enzymes in specific cells, and discovered new methods for the site-specific modification of antibodies for enhanced cancer therapeutics.

Richard R. Schrock

In the year 2014-2015 the Schrock lab has continued to develop new molybdenum and tungsten catalysts for the metathesis of olefins and use them to synthesize stereoregular polymers and organic molecules. The main achievement in the former category is the ability to prepare both pure isotactic and pure syndiotactic hydrogenated polydicyclopentadiene, which is a commercial target as a high melting hydrocarbon polymer. The lab has also restarted its research on the catalytic reduction of molecular nitrogen to ammonia, which is now considered to be an option for making and storing molecular hydrogen.

Alex K. Shalek

This year the Shalek Lab co-developed an ultra-high-throughput, low-cost, droplet-based single-cell RNA-Seq technology called “Drop-Seq.” In this methodology, cells are first separated into nanoliter-sized aqueous droplets, where a unique barcode is associated with each cell’s mRNA, before they are sequenced together. This technique allows for simultaneous analysis of mRNA transcripts from thousands of individual cells while still retaining each transcript’s cell of origin. Using this approach, 44,808 primary mouse retinal cells were profiled to reveal 39 transcriptionally distinct cell populations, creating a molecular atlas of gene expression for known retinal cell classes and novel candidate cell subtypes. Shalek envisions that Drop-Seq will accelerate biological discovery by enabling routine and cost-effective transcriptional profiling at single-cell resolution, affording researchers the opportunity to identify, from first principles, the cell types and states found in their complex samples, such as a healthy or diseased tissue, and their associated molecular signatures. His lab is currently working to realize a clinically deployable variant of the approach to help usher in and inform an era of precision medicine.

Matthew D. Shoulders

The Shoulders lab develops chemical biology methods to modulate the metazoan protein homeostasis machinery and applies their methods in diverse protein misfolding-related disease model systems. In particular, they devised small molecule-mediated techniques to regulate cellular protein folding capacity and applied those methods to demonstrate that viral evolution depends critically on assistance from viral host cell protein folding chaperones. Other highlights included the first mapping of the collagen-I proteostasis network and the discovery that the unfolded protein response regulates the molecular architecture of the mature N-glycome.

Yogesh Surendranath

Research in the Surendranath group aims to use electricity to rearrange chemical bonds by manipulating interfacial reactivity at the molecular level. The group's approach led to two key breakthroughs: 1) the discovery of a universal deactivation mechanism for metal-based carbon-dioxide fixation catalysts, and 2) the development of a new class of molecularly precise heterogeneous catalysts that feature discrete active sites in conjugation with the extended states of graphite.

Timothy M. Swager

Swager's research lab has continued to focus on the chemiresistive sensing of gases, with an emphasis on agricultural and food applications. Specifically they have published on the development of wireless sensors that can be both powered and read by smart phones. These non-line-of-sight detection methods are powerful in that they are very low cost and can be integrated directly into food packaging. A pairing of this technology with Swager's selective sensors for compounds emitted by decaying meat or fish has transitioned to C2 Sense, a new MIT spinout company. A new direction for Swager's group this year has been in the area of dynamic complex liquid colloids and these systems promise to be the basis of a number of new photonic and sensor technologies.

Alice Y. Ting

This past year, the Ting laboratory has mapped the proteome of the synaptic cleft in living neurons, using a peroxidase-mediated proximity tagging method it reported in 2013. The resulting proteomic lists—of excitatory synaptic clefts and inhibitory synaptic clefts, separately—reveal several novel synaptic proteins and highlight the distinct localizations of the MDGA proteins, which led the lab to discover a novel function for MDGA2 in regulating the specificity of inhibitory synapse formation. The lab also made progress towards the development of a genetically encoded reporter for discovering novel neuronal circuits underlying specific mouse behaviors. This reporter consists of a transcription factor activated by the coincidence of light and high calcium, and can be used to reactivate neurons that are stimulated during specific processes. In addition to being a powerful research tool, this reporter could potentially be used for "mind control" in animals.

Jeffrey Van Humbeck

Academic year 2015 was the first year of the Van Humbeck laboratory. The lab began a series of investigations that looked at the use of structured porous polymers as a support for selective catalysts, with initial experiments pursued in the context of medicinal chemistry and petrochemical applications. A series of fundamental investigations aimed towards the development of new and more selective homogeneous catalysts was also launched. The laboratory has begun investigating the inclusion of permanently charged sites in typically neutral catalyst structures, and also began developing rigid scaffolds that help to direct catalytic reactions to a particular region of a complex substrate.

Troy Van Voorhis

In the past year, the Van Voorhis group has continued its efforts to understand the electronic structure of photochemical and photovoltaic systems. Their biggest contribution in the past 12 months has been an understanding of the mechanism of light emission in organic LEDs. Their theory accurately predicts that recombining charges recombine via an "inchworm" mechanism, whereby the tethered electron and hole move a significant distance before emitting. These discoveries could help the design of efficient LED-based indoor lighting.

Sylvia T. Ceyer
Department Head
J. C. Sheehan Professor of Chemistry