Department of Chemical Engineering

During the 2009–2010 academic year, the Chemical Engineering Department continued to lead the field in key academic research areas, including the engineering–life science interface, pharmaceutical manufacturing, and energy and the environment. The department has also retained its number-one ranking in *US News and World Report* in both undergraduate teaching and graduate programs; we have now held the top position in chemical engineering for the past 21 years. Sponsored research volume increased significantly once again for our chemical engineering faculty, rising from last year's $41.2 million to a total of $50.4 million over the past year, representing a 22% increase; $26.6 million of these research funds are directly handled through the department, with the remainder associated with other cost centers at the Institute.

A number of faculty were funded in new and critical areas championed by the US government. For example, department faculty have recently been funded by the new Department of Energy–sponsored Advanced Research Projects Agency–Energy program, a highly competitive fund designed to promote energy innovation in the United States. This includes a project of professor T. Alan Hatton on electrochemically mediated separation for carbon dioxide capture, a microbe-based process for generating oil from hydrogen and carbon dioxide led by professor Gregory N. Stephanopoulos, and a semisolid flow cell battery concept in which professor Paula T. Hammond is a co-investigator. Chemical engineering faculty remain strongly represented among research projects funded by the MIT Energy Initiative (MITEI), and new projects have also been funded by Saudi Aramco for professors Karen K. Gleason and William H. Green. New research efforts in biomaterials and biotechnology were also funded by numerous institutions such as the Ragon Institute and the David H. Koch Institute for Integrative Cancer Research. Chemical engineering faculty play important roles within those institutes. Chemical engineering research is supported by industry as well as defense and government institutions such as the National Institutes of Health (NIH) and the National Science Foundation (NSF).

Professor Klavs F. Jensen continues his term as department head, as does professor Paula T. Hammond in her role as executive officer. The administration has worked with facilities coordinator Steve Wetzel and several other faculty and staff members to help the department repair and recover from much of the damage to the building caused by the steam explosion that occurred in the previous academic year. Professor William M. Deen remains the department's graduate officer, and Barry Johnston continues to serve as undergraduate officer. After three years of very selective incoming graduate classes, professor Arup K. Chakraborty has completed his term as the graduate admissions chair; during this time, we enjoyed high yields due to his key efforts in graduate student recruiting. One of our newest senior faculty members, professor Richard D. Braatz, will head up graduate admissions starting this coming academic year. The department remains honored to be the only department with two Institute Professors, Daniel I.C. Wang and Robert S. Langer, as primary department members.

Many New Faces

This academic year we were fortunate to have several new faculty members who joined the department or will join us in the near future. Three candidates who were extended offers in the previous two academic years have completed their postdoctoral studies and fellowships and arrived on campus. Professor Hadley D. Sikes, whose research is in the bioengineering of redox-active nanomaterials for cancer and biomedical applications, began her position as assistant professor in September 2009 and Bradley D. Olsen, who is working on polymeric and protein-based self-assembled materials systems, officially joined the department in January 2010, also as assistant professor. We anticipate the arrival of assistant professor Yuriy Román, whose work is in reaction kinetics and design, in September 2010.

We also have three new tenured or tenure-track faculty members who were extended offers during the 2009–2010 academic year. Professor Richard D. Braatz has recently been recruited as a full professor to the department; he was previously the Millennium Chair and professor of chemical and biomolecular engineering, electrical and computer engineering, mechanical science and engineering, and bioengineering at the University of Illinois in the Chemical Engineering Department and has spent the past academic year in Cambridge as a Harvard fellow during his sabbatical. Professor Braatz was also a visiting professor in our department during a previous sabbatical in 2003. Professor Braatz's research group examines the creation of methods for the simulation, design, and control of multiscale systems that have length scales ranging from the atomistic to the macroscopic. His mechanistic models address a broad range of applications, including lithium ion batteries, nanotube-based sensors, and degradation and release processes in polymeric nanoparticles for drug release. These materials applications are in collaboration with experimentalists who validate model predictions and system designs.

Professor Daniel G. Anderson, formerly a research associate in the Langer laboratory, has been appointed as a dual junior faculty member in Chemical Engineering and the Harvard-MIT Division of Health Sciences and Technology. He is also a member of the Koch Institute for Integrative Cancer Research. His research focuses on the use of rapid assay approaches for the generation of new biomaterials for medical applications. He received his PhD in molecular genetics from the University of California at Davis. At MIT, he pioneered the use of robotic methods for the development of smart biomaterials for drug delivery and tissue engineering. He has developed methods allowing rapid synthesis, formulation, analysis, and biological testing of large libraries of biomaterials for use in medical devices, cell therapy, and drug delivery. In particular, the advanced drug delivery systems he has developed provide new methods for nanoparticulate and microparticulate drug delivery, nonviral gene therapy, siRNA delivery, and vaccines.

Dr. Fikile Brushett has recently accepted an offer as assistant professor; he recently completed his doctoral work at the University of Illinois, which focused on developing microfluidic-based electrochemical systems (i.e., fuel cells) as flexible power sources and powerful analytical platforms under the supervision of professor Paul J.A. Kenis. Fikile will be joining the department after a postdoctoral stay at Argonne National Laboratories where he will be developing new electrochemically active materials and novel chemistries for room-temperature nonaqueous flow batteries with high energy efficiency and operating voltage under the supervision of Dr. John Vaughey and Dr. Dennis Dees. As a faculty member, Fikile will be investigating electrochemical processes for energy storage and conversion applications with a focus on addressing fundamental questions related to the performance and durability of the catalysts, electrodes, and internal interfaces within these systems. He will use novel microfluidic and micro-/nanotomographic approaches, in concert with conventional electrochemical and surface characterization techniques, to identify, understand, and optimize the critical underlying processes within operating electrochemical systems.

Finally, our department is welcoming its first professor of the practice. The position of professor of the practice at MIT is a non-tenure-track faculty position that is made for practitioners who have developed a high level of expertise in fields of particular importance to the MIT academic program and who also demonstrate a deep commitment to teaching and research. The position provides an opportunity for a highly experienced and well-respected member of the field to bring a new perspective to the department's educational and research programs. Professor Allan S. Myerson, who will join us this fall, is a leading expert on industrial crystallization. His papers have opened up new ways of studying crystallization and provided new insights in and understanding of nucleation phenomena and crystal growth. His work on polymorphism, crystal aging, and metastable solution properties has had a tremendous impact on industrial practice. Allan has a wealth of practical experience as consultant to more than 70 pharmaceutical companies; he is also a founder and long-serving editor of the American Chemical Society (ACS) journal on crystallization, *Crystal Growth & Design*. Allan comes to MIT from his former position as the Philip Danforth Armour professor of engineering at the Illinois Institute of Technology (IIT) in chemical and biological engineering. He also served as the provost, senior vice president of research, and dean of engineering during his time at IIT. At MIT, he will continue to conduct research in pharmaceutical crystallization and will teach in the chemical engineering curriculum.

Along with the many new arrivals, we have also had some retirements and departures, including those of professors Herbert H. Sawin and Kenneth A. Smith. Both faculty members remain connected to the department in many ways. Professor Gregory J. McRae also retired to take on new opportunities and responsibilities with Morgan Stanley. We bade farewell to professor Jefferson W. Tester as he completed his move to Cornell University to lead the new Cornell Center for a Sustainable Future.

Our faculty enjoyed several national recognitions over this past year. Professor Robert E. Cohen was elected to the National Academy of Engineering and was also elected as a Materials Research Society Fellow. Professor Klavs F. Jensen was elected as a fellow in the American Institute of Chemical Engineers (AIChE). Professor Paula H. Hammond was elected to the American Institute for Medical and Biological Engineering (AIMBE). Professor Kristala J. Prather won the NSF CAREER Award. Professor Gregory N. Stephanopoulos won the 2010 American Chemical Society E.V. Murphree Award and the BIO George Washington Carver Award for Innovation in Industrial Biotechnology. Professor Michael S. Strano's work was cited as one of *Popular Science*'s Brilliant 10 last fall, and junior faculty member J. Christopher Love was named the W.M. Keck Foundation Young Scholar in Medical Research. Of particular note is awarding of the

AIMBE Pierre Galletti Award, which is the AIMBE top honor, to professor emeritus Edward Merrill this spring. In May, the department honored Ed's accomplishments at a gathering designed to celebrate his 60 years as a faculty member at MIT; the event included a symposium with lectures from many of his former students and mentees from across the globe, including our own professors Robert S. Langer and Clark K. Colton as well as David A. Tirrell '74 of the California Institute of Technology and Nicholas A. Peppas '73 of the University of Texas at Austin.

There were many news items related to the activities of our faculty. Some highlights include the discovery of a new phenomenon in the Strano lab: a thermopower wave generated across single-wall nanotubes that could lead to new forms of electricity generation, as outlined in a publication in *Nature Materials*. By modeling immune cells that develop in the thymus, professor Arup K. Chakraborty and coworkers discovered a rare gene that helps resist the AIDS virus, a significant advance toward development of an AIDS vaccine; this work was published in the journal *Nature*. Professor Narendra Maheshri published new findings on the nature of transcriptional feedback in gene regulatory networks in the journal *Science*. Professor Karen K. Gleason has generated new paper solar cells that are created by a simple approach with chemical vapor deposition of carbon and polymer "inks," and professor Paula T. Hammond had the opportunity to describe her solar research on virus batteries and solar cells, with collaborator professor Angela Belcher, to President Barack Obama during his visit to MIT last October.

Undergraduate Education

Since 2004, the Department of Chemical Engineering has offered bachelor of science (SB) degrees in both chemical engineering (Course 10) and chemical-biological engineering (Course 10-B). Department undergraduate enrollment continues to remain strong: around 240 students in recent years. Chemical Engineering currently has the highest student-to-faculty ratio in the School of Engineering. The department advises students about career paths in chemical and chemical-biological engineering through active participation in freshman advising seminars, fall- and spring-term open houses, parents' weekend, and other activities. Overall, 73 SB degrees were conferred as of June 2010, with 55% awarded to women. Student quality remains excellent. The distribution of undergraduate students by class over the last 10 years is shown in the table below.

Undergraduate Enrollment over the Last 10 Years

Class year	00–01	01–02	02–03	03–04	04–05	05–06	06–07	07–08	08–09	09–10
Sophomores	67	47	56	56	95	100	95	96	87	87
Juniors	76	66	49	43	55	83	75	67	77	68
Seniors	89	84	65	41	55	53	83	77	75	73
Total	**232**	**197**	**170**	**140**	**205**	**236**	**253**	**240**	**239**	**228**

The 10-B program leading to the accredited SB degree in chemical-biological engineering was introduced in 2004 in response to demand from our students for a focused and coherent educational curriculum in biological aspects of chemical engineering, with more in-depth training in advanced modern chemical and molecular biology. The program embodies three primary components: (1) a core in advanced biology, comprising biochemistry, genetics, and cell biology; (2) a core in engineering science comprising mass and energy balances, thermodynamics, heat, mass and momentum transport, and chemical kinetics; and (3) a capstone design experience that emphasizes problems in chemical-biological engineering while teaching integration and synthesis of fundamental science principles for solving engineering problems and understanding complex systems. Student participation in Course 10-B has been very robust since the outset, with undergraduate enrollment rising from 20 students in 2004 to 105 in 2006, 143 in 2008, and a solid 125 in 2010. Currently, students in the chemical-biological engineering program constitute 55% of the undergraduates in the Department of Chemical Engineering. Forty-four seniors graduated with degrees in chemical-biological engineering in the Class of 2010, and 37 freshmen in the Class of 2013 declared their majors in chemical-biological engineering.

The average starting salary for graduates of the Department of Chemical Engineering is $63,256 (2010 senior survey), which is among the highest in the School of Engineering. This attests to the success of the graduates of the 10 and 10-B programs in the department and to the continued high demand for our students. The senior surveys indicate that, between 2001 and 2008, 50% to 60% of our students went on to graduate or professional school.

Undergraduates in the Department of Chemical Engineering maintain an active student chapter of AIChE, with invited speakers, presentations at national meetings, and visits to company sites. The student officers of AIChE were Katrina Westerhof (president), Apiradee Sanglimsuwan (vice president), Mindy Du (secretary), Alexandra Piotrowski (treasurer), Shan Tie (Class of ’10 representative), and Elizabeth Ohrt (Class of ’11 representative).

Graduate Education

The graduate program in the Department of Chemical Engineering offers master of science degrees in chemical engineering (SM) and in chemical engineering practice (MSCEP), doctor of philosophy (PhD) and doctor of science (ScD) degrees in chemical engineering, and PhD degrees in chemical engineering practice (PhDCEP). The PhDCEP track was established in 2000 in collaboration with the Sloan School of Management. The total graduate student enrollment is currently 241, with 203 in the doctoral program and 38 master-level degree candidates. In the doctoral program, 211 students are in the PhD/ScD track and 13 are in the PhDCEP track. In the master-level program, 28 are in the MSCEP track. Twenty-nine percent of our graduate students are women. Two percent are underrepresented minority students. Forty-one of our graduate students were recipients of outside fellowship awards from NSF, NIH, the Department of Defense, and others. The distribution of graduate students by degree for the last 10 years is shown in the table below. During the 2009–2010 academic year, 32 doctoral degrees (29 PhD or ScD, 3 PhDCEP) were awarded, along with 42 master-level degrees (33 MSCEP, 9

SM) for a total of 74 advanced degrees conferred. Thirty students passed the doctoral qualifying exams and were promoted to candidacy for the PhD/ScD or PhDCEP. The department received 350 applications for admission to the doctoral program, offered admission to 57 individuals, and received 40 acceptances of offers, for an acceptance percentage of 71%. Of 79 applications for master-level degrees, the department made 23 offers and received 16 acceptances of offers, for a yield of 70%. Among the incoming graduate class for 2010, 21 are women and one is an underrepresented minority. On average, the incoming graduate class held an undergraduate grade point average of 4.95 (out of 5.0).

Graduate Enrollment over the Last 10 Years

Degree level	00–01	01–02	02–03	03–04	04–05	05–06	06–07	07–08	08–09	09–10
Master's	40	38	36	26	19	16	18	26	32	38
Doctoral	166	209	245	232	216	203	217	212	228	203
Total	**206**	**247**	**281**	**258**	**235**	**219**	**235**	**238**	**260**	**241**

Research Centers

The Department of Chemical Engineering is actively involved and takes a leadership role in several Institute-wide education and research programs. A few of these are highlighted here.

Singapore–MIT Alliance

The Department of Chemical Engineering's Singapore–MIT Alliance program (SMA-2), called Chemical and Pharmaceutical Engineering (CPE), completed its fourth year on June 30, 2010. Professor Bernhardt L. Trout is co-chair of this program along with professor Raj Rajagopalan of the National University of Singapore. There are currently 56 students in the program, 26 dual master degree candidates, and 30 direct-entry PhD students. The research part of CPE focuses on metabolic engineering, chemical catalysis, and downstream processing. The MIT faculty involved with CPE are professors Daniel Blankschtein, Patrick S. Doyle, T. Alan Hatton, Kenneth A. Smith, Gregory N. Stephanopoulos, Bernhardt L. Trout, and Daniel I.C. Wang.

DuPont–MIT Alliance

The DuPont–MIT Alliance (DMA) is a research and educational partnership between MIT and DuPont. The goals and aims of DMA are to foster collaboration in research efforts that include technology related to chemical, biochemical, and material sciences and to promote educational activities that are of mutual interest and benefit to MIT and DuPont.

Governance

A steering committee is responsible for the direction of research and educational activities. The committee meets biannually. The current steering committee members on the MIT side of the board include director Claude Canizares, vice president for research and associate provost; associate director Robert E. Cohen, St. Laurent professor of chemical engineering; and Bruce Tidor, professor of biological engineering and computer science. The daily supervision of the program is managed by Patricia Reilly, assistant director. The DuPont director is Dr. Uma Chowdhry, supported by the DuPont associate directors: Drs. Henry Bryndza, Steven Freilich, and Roger Siemionko with the assistance of the project director Dr. Wayne Marsh. Later this year the directorship will be transferred to Dr. Doug Muzyka.

Research Focus

Partnering with MIT has helped to bring new research and technologies to DuPont. The direction of the research projects is determined by the unanimous vote of the steering committee. At present, there are 14 research projects under the direction of professors Daniel Blankschtein, T. Alan Hatton, Narendra Maheshri, Gregory C. Rutledge, and Michael S. Strano as well as several research activities at Lincoln Laboratory. The total annual budget for research activities is $2,733,000.

Educational Activities

The education thrust promotes participation at the investigator level as well. This academic year, three fellowships were awarded to the following newly hired associate professors to assist in their research programs:

- Hyukmin Kwon, under the mentorship of Kripa Varanasi, Mechanical Engineering
- Hsieh Chen, under the mentorship of Alfredo Alexander-Katz, Materials Science and Engineering
- Muzhou Wang, under the mentorship of Brad Olsen, Chemical Engineering

As the alliance continues to grow, DMA remains dedicated to the principles of novelty and excellence. There is a unique cooperation between DuPont and MIT to promote the basic principle of collaborative research that will have a significant impact on the long-term commercial goals of DuPont and the continuously evolving educational culture of MIT.

Faculty Notes

Professor Robert C. Armstrong continues to serve as deputy director of MITEI, which continues to grow rapidly in its research, educational, campus, and outreach components. Fifteen companies and public institutions sponsor research as founding and sustaining members of MITEI; the energy initiative has about 60 industrial partners overall. MITEI has helped to bring in approximately $300 million in support over its first three years of operation and around 120 energy graduate fellowships spread over 19 departments. This year Professor Armstrong was elected to serve on the AIChE board of directors. During this past academic year, he gave lectures at Rice University, the University of Houston, and Schlumberger. He chaired the review of the Department of Energy's solar programs and serves on the advisory boards of chemical engineering departments at Georgia Tech; Northwestern University; Texas A&M; the University of Colorado, Boulder; the University of Washington; and Washington University. He also serves on the advisory board of the ASP program at Politecnico di Torino, Italy.

Professor Martin Z. Bazant continued his research in transport phenomena, focusing on electrochemical and microfluidic systems. He made theoretical advances in capacitive charging of porous electrodes, phase transformations in Li-ion batteries, and flows over superhydrophobic surfaces. He recently invented an approach to desalination, "shock electrodialysis," taking advantage of nonlinear transport phenomena in micro-/nanochannels, and the first experiments in his new laboratory are focusing on this topic. He presented a plenary lecture on "Induced-Charge Electrokinetics in Microfluidics" at the International Electrokinetics Symposium in Turku, Finland, in June 2010, and he wrote an invited article for the first issue of *Current Opinion in Colloid and Interface Science* focusing on electrokinetics. In 2009, he began leading an NSF focused research group on mathematical modeling of lithium-ion batteries. In spring 2010, he taught his new subject 10.626 Electrochemical Energy Systems and developed original course materials. He also coached an unprecedented number of MIT undergraduates in the mathematical contest in modeling and helped the students form a club; of five teams competing in 2010, two won the "meritorious" ranking.

Professor Daniel Blankschtein's research group conducts fundamental theoretical and experimental research in the area of colloid and surfactant science, with emphasis on industrial and biomedical applications. Professor Blankschtein's teaching responsibilities included the Program in Polymer Science and Technology core graduate subject 10.55 Colloid and Surfactant Science in fall 2009 and the development of an advanced subject in colloid science in spring 2010. Professor Blankschtein and his students delivered talks at the 2009 AIChE Annual Meeting and at the DMA Faculty Symposium in May 2010. He is a member of the editorial board of Marcel Dekker's *Surfactant Science Series*.

Robert T. Haslam professor Arup K. Chakraborty had a productive year in teaching and research. In research, he continued to make advances in T-cell signaling and T-cell repertoire development and launched new efforts on T-cell lymphomas and the human immune response to HIV. In these endeavors, his lab brought together statistical mechanical approaches, rooted in physics and engineering, with experimental studies carried out by collaborators who are basic immunologists and clinicians. Perhaps the most significant study emerging from Chakraborty's laboratory this year is the discovery of an effect that contributes to the ability of people with certain genes to control HIV infections. This effect originates from differences during T-cell development that result in people with certain genes having a more cross-reactive T-cell repertoire, which can mount strong immune pressure on the infecting HIV strain and mutants that emerge during infection. The paper describing this work was published in *Nature* and was the subject of more than 100 news stories in scientific journals as well as the international popular media (e.g., *Time*, BBC, Voice of America). Chakraborty continues to be a member of the steering committee of the Ragon Institute of Massachusetts General Hospital, MIT, and Harvard. He is also the leader of one of the four projects that are a part of the recently established NIH-funded Physical Science–Oncology Center at MIT. Additionally, Chakraborty taught two mandatory subjects in chemical engineering for the first time. First, he developed a new version of the core graduate subject in thermodynamics, which aims to provide students with knowledge pertinent to modern chemical engineering research. Second, he co-taught the core undergraduate subject in fluid mechanics. Both subjects received favorable evaluations from students. As chair of the graduate recruiting committee for chemical engineering, Chakraborty led another very successful recruiting effort. He also participates in various teaching and research activities in the Department of Chemistry and served on the committee that advised the dean of science regarding the appointment of the new head of the Chemistry Department. Chakraborty also serves as an editor of *Biophysical Journal*, on numerous editorial boards, university and government advisory boards, and committees of the National Academy of Engineering and American Association for the Advancement of Science.

Professor Robert E. Cohen was elected to the National Academy of Engineering in 2010. He was honored with an Astor visiting lectureship at Oxford University where he spent a week in residence at Balliol College and lectured on designing omniphobic surfaces in the Department of Engineering Sciences. He was also among this year's group of new Materials Research Society fellows. At the Institute, Cohen continued to lead the operations of the DMA. In other administrative contributions, he assumed leadership of the Program in Polymer Science and Technology, a four-department program for doctoral students who have interests in various aspects of macromolecular science and engineering. Cohen also headed the Chemical Engineering Department's PhDCEP, a collaborative program with the Sloan School of Management.

Professor Clark K. Colton's research group continued its efforts to develop improved methods for maintaining and differentiating stem cells for use in regenerative medicine. Professor Colton received a grant from the Juvenile Diabetes Research Foundation to collaborate with Novocell Inc. on differentiation of human embryonic stem cells to insulin-secreting cells for curing diabetes. He also received an American Recovery and Reinvestment Act challenge grant for developing modified oxygen-permeable polymers to enable culture of human embryonic stem cells at precisely defined oxygen partial pressure.

Professor Charles L. Cooney, the Robert T. Haslam (1911) professor of chemical and biochemical engineering, continued as faculty director of the Deshpande Center for Technological Innovation. He chairs the ad hoc faculty committee on MIT Technology Transfer in the 21st Century and serves on the Innovation Engagement Committee, the NIH Engagement Committee, the Knight Science Journalism Fellowships Advisory Board, the Advisory Committee for Regional Engagement, the MIT Community Service Fund Board, and the MIT Committee on Intellectual Property. He is co-chair of the MIT's India Strategy Working Group and serves on the MIT–Sanofi Aventis Joint Scientific Steering Committee, the executive committee of the Masdar Institute of Science and Technology (Abu Dhabi), the Center for Biomedical Innovation Steering Committee, the steering committee of the bioengineering section of the MIT Portugal Program, and the steering committee of the Novartis–MIT Center for Continuous Manufacturing. He is co-chair of the MIT Manufacturing Innovation Initiative and the executive committee of the Legatum Center for Development and Entrepreneurship; he participated in the Sloan Executive Education Programs and was on the advisory committee to the SMART Innovation Center. Professor Cooney is a member of the National Institute of Standards and Technology's Technology Innovation Program Advisory Committee and the Massachusetts Life Sciences Collaborative Advisory Committee. He is faculty director of the Downstream Processing summer course offered through MIT Professional Education. His research focuses on pharmaceutical manufacturing technology and technological innovation. He gave the Hoehn Lecture at Northeastern University in May 2010. Professor Cooney is also an overseer of the Boston Symphony Orchestra and a trustee emeritus of Boston Ballet.

Professor Patrick S. Doyle spent the fall on sabbatical at the Institute Curie and the École Supérieure de Physique et de Chimie Industrielles (ESPCI) in Paris. This sabbatical visit was funded by a John Simon Guggenheim Fellowship and Joliot Chair from the City of Paris. He continued work in the area of fundamental studies of complex fluids in microfluidic devices. Professor Doyle was invited to deliver the Stratis V. Sotirchos Memorial Lectureship at FORTH/ICE-HT in Greece. This award recognizes an engineer-scientist under the age of 40 who has produced original and fundamentally important results in some research and development field within the broader context of chemical engineering. His work in the area of barcoded particles for diagnostics resulted in the creation of a small company, Firefly Bioworks, which is located in the Cambridge area. He gave a number of invited lectures at various institutes including the Ragon Institute, ESPCI, Institute Curie, Genomic Vision, University of Twente in the Netherlands, and Catholic University of Leuven in Belgium.

Professor Karen K. Gleason continued her second year in the role of associate dean of engineering for research, overseeing and fostering interdisciplinary and international research centers reporting to the School of Engineering. Her group continues to develop the fundamental science behind the chemical vapor deposition of polymers as well as the engineering required to transition this technology. In the past year, this research has been published in invited feature articles and reviews in *Advanced Materials*, *Materials Today*, and *Physical Chemistry and Chemical Physics.* Additionally, Professor Gleason served as guest editor for a special issue of *Chemical Vapor Deposition* devoted to the topic of chemical vapor deposition polymer films. Professor Gleason delivered numerous invited lectures, including a keynote address at the 11th Pacific Polymer Conference, Cairns, Australia, and at the 23rd International Conference on Amorphous and Nanocrystalline Semiconductors, Utrecht, Netherlands. Professor Gleason continues to serve as chief scientific advisor to GVD Corporation, a technology company she cofounded to commercialize inventions from her laboratory. GVD is headquartered in Cambridge, MA, and recently established a facility devoted solely to commercial manufacturing in Greenville, SC.

Professor William H. Green was named the Hoyt C. Hottel professor of chemical engineering in December. He developed methods for modeling combustion chemistry and used them to accurately predict the behavior of several alternative fuels. He plays key roles in the new Department of Energy Combustion Energy Frontier Research Center, the new Saudi Aramco–MIT project on fuel desulfurization, and MITEI's project on conversion with CO_2 sequestration. He is editor of the *International Journal of Chemical Kinetics* and lead organizer for the 7th International Conference on Chemical Kinetics, which will be held at MIT in July 2011.

As executive officer, professor Paula T. Hammond has been working with fellow chemical engineering colleagues on developing the undergraduate program, including increased flexibility in the integrated chemical engineering modules and laboratory courses. She has also completed chairing the provost's Initiative on Faculty Race and Diversity, a three-year process that is anticipated to have a long-term impact on MIT and its efforts toward increasing faculty diversity. The report from the initiative was publicly released on Jan 14, 2010, and MIT has been highly visible in its release and its response to the report. Professor Hammond was honored with the 2010 Distinguished Scientist Award at Harvard University, presented by the Harvard Foundation. This year, she was elected a fellow in AIMBE. She was the University of California, Berkeley, Melvin Calvin lecturer in the Berkeley Department of Chemistry and recipient of the William Grimes Award presented by the Minority Affairs Committee at AIChE. Her research effort on electrostatic assembly of carbon nanotubes, conducted jointly with professor Yang Shao-Horn in Mechanical Engineering, was published in *Nature Nanotechnology* in June 2010 and is the basis of several new efforts to generate high-power, high-capacity battery electrodes with this water-based assembly approach. Last October, Professor Hammond had the opportunity to meet President Barack Obama to discuss MITEI-sponsored work with Angela Belcher on virus batteries and photovoltaics during his visit to speak at the Institute on energy policy. Continued research on cancer drug delivery systems involving targeted peptide-dendrimers and thin-film drug release coatings has led to the publication of a key article on the use of dendritic systems to direct cluster-ligand targeting for tumor therapies, which will be published in *Angewandte Chemie*. Her work on electrostatic assembly for drug delivery has led to several publications and a series of collaborative and industrial efforts ranging from transdermal vaccine delivery to wound healing and regenerative tissue repair. Finally, last year, Professor Hammond was involved in the startup of a new company, Svaya Nanotechnologies, that was cofounded by her former graduate student, Kevin Krogman, and is based on the generation of functional coatings using spray layer-by-layer systems patented in her lab.

Professor T. Alan Hatton continued to serve as director of the David H. Koch School of Chemical Engineering Practice, where he has maintained the international flavor of the program by placing student teams at host companies in Switzerland, Italy, and India in addition to the United States. He also directed the National Renewable Energy Laboratory station in Golden, CO, for one session. He is an active participant in the SMA program on chemical and pharmaceutical engineering. Professor Hatton is a member of the scientific advisory boards of the Particulate Fluids Processing Centre at the University of Melbourne and of the GSK–Singapore Partnership for Green and Sustainable Manufacturing in Singapore. Over the past year, he has given a number of invited lectures at the American Chemical Society (ACS) and AIChE meetings as well as talks at the Engineering Conferences International (ECI) on Association in Solution in Tomar, Portugal. Seminar invitations included those by the Indian Institutes of Technology in Mumbai, Delhi, and Roorkee as well as the Institute of Chemical Technology in Mumbai, the University of Melbourne, Australia, and the Swiss National Institute of Technology in Zurich (ETH Zurich). Professor Hatton is on the technical committee of the International Solvent Extraction Conference 2011 in Santiago, Chile, and ECI Separations Conference in Hawaii, 2010. He is on the editorial advisory boards of *Current Opinion in Colloid and Interface Science* (as coeditor of the section on Applications), *Chemical Engineering Research and Design*, and *Langmuir*. He is an advisory board member of ECI in New York.

Professor Klavs F. Jensen continues his research on functional micro- and nanostructured materials and devices for chemical, optical, and electronic applications. With collaborations in chemistry, he has explored a wide range of microfabricated systems for chemical and biological applications with particular emphasis on systems for which microfabrication provides unique process advantages. These systems also form the basis for continuous flow synthesis and separation developments as part of the new Novartis–MIT Center for Continuous Manufacturing. The ability to operate at high pressure and temperature conditions not easily achieved in batch is being exploited in the synthesis of nanoparticles for optical and catalytic applications relevant to energy conversion through MITEI-sponsored projects. In addition to his responsibilities as department head, he co-chaired (with associate provost Philip Khoury) the revenue enhancement subgroup of Institute-wide Planning Task Force. He was elected a fellow of AIChE. During the past academic year, he gave plenary lectures on microreaction technology at conferences, including Labautomation, ACS, and AIChE. He continued to serve on the governing board of the Technical University of Denmark and on the scientific advisory board for the Singapore A*STAR Institute for Nano and Biotechnology.

This year professor Jesse H. Kroll began his research program in the chemistry of atmospheric organic particulate matter. His lab (located in Parsons Lab, Building 48) was completed last summer, and his group is currently setting up reactors and instruments for the laboratory study of atmospheric reactions. The group also participated in the CalNex 2010 atmospheric chemistry field campaign in Pasadena, CA, and carried out experiments at the Advanced Light Source in Berkeley, CA. Professor Kroll gave an invited talk at the Gordon Research Conferences in Atmospheric Chemistry as well as invited seminars at Harvard University, Woods Hole Oceanographic Institute, the University of Rhode Island, and Bowdoin College.

In 2009 and 2010, Robert S. Langer received honorary degrees from Harvard University, the Mount Sinai School of Medicine, Rensselaer Polytechnic Institute, and Willamette University. He also received the University of California, San Francisco, Medal; the Engineering in Medicine and Biology Society's EMBS Award; the New England Institute of Chemists Distinguished Chemist Award; and the Massachusetts Society for Medical Research Biomedical Research Leaders Award. He was elected to the Controlled Release Society College of Fellows and as a Founding POLY fellow for the ACS Division of Polymer Chemistry.

Professor J. Christopher Love continued to develop new analytical processes for profiling immune responses to chronic diseases and assessing clonal variation in biomanufacturing processes using single-cell microtechnologies. He was named a Keck Foundation Distinguished Young Scholar in Medical Research. He delivered invited lectures at various locations including the MITRE Corporation, Novartis Vaccines, Rice University, and the Gladstone Institutes at the University of California, San Francisco. The Love laboratory published the first example of measuring polyfunctional cytokine responses from viable human T cells in a manner that allows subsequent cloning in vitro. The research was featured on the cover of *Lab on a Chip* in May 2010.

Professor Narendra Maheshri continues his fundamental studies on the dynamics of eukaryotic gene regulation as well as technological approaches to generating phenotypic diversity. This past year, his group has demonstrated how combining in vivo single-cell dynamic measurements of fluctuations in gene expression with modeling approaches enables a deeper understanding of how two gene "switches" work. A study in *PLoS Genetics* describes how epigenetic inheritance can be modulated with a gene switch that relies on slow, stochastic, promoter remodeling and was featured in March 2010 in *Nature* magazine's Journal Club section. A second study in *Science* provides experimental proof that stochastic dynamics in gene expression helps create a gene switch and was recommended by the Faculty of 1000 Biology.

Bradley D. Olsen joined the Department of Chemical Engineering as an assistant professor at the end of December 2009 after completing his postdoctoral work at the California Institute of Technology. His new research program focuses on developing hydrogels and bioelectronic materials prepared from artificial protein polymers and protein-polymer hybrids. In addition, his group is working to address fundamental problems in polymer science by using biosynthesis to prepare model polymers with uniquely controlled molecular structures. During the spring, he was a co-instructor for subject 10.10 Introduction to Chemical Engineering and continued to publish papers in the fields of block copolymers and polymer hydrogels.

Professor Kristala J. Prather is continuing her research, primarily in the areas of metabolic engineering and synthetic biology. In addition to several presentations at professional conferences, she gave 12 invited lectures, including presentations at the Biotechnology Industry Organization World Congress on Industrial Biotechnology and Bioprocessing (Montreal, Quebec, Canada), the Ontario Genomics Institute Synthetic Biology Symposium (Toronto, Ontario, Canada), the Mathematical Biosciences Institute Workshop on Synthetic Biology (Columbus, OH), and the 110th Annual Meeting of the American Society for Microbiology (San Diego, CA). Prather served as a special editor for a focus issue of *Biotechnology Journal* on synthetic biology and she continues to be actively involved in the Synthetic Biology Engineering Research Center (SynBERC). Her SynBERC-sponsored research in collaboration with John Dueber and Jay Keasling (University of California, Berkeley) was published in *Nature Biotechnology* and was subsequently highlighted in a feature article in a special issue of the journal focused on synthetic biology (Engineering a new business, 27(12):1112–1120, 2009). The first two thesis defenses of Prather lab students were successfully presented in November 2009. Finally, Prather received an NSF CAREER Award in March 2010.

Professor Gregory C. Rutledge returned to the department in August 2009 after a year as visiting faculty in the School of Engineering and Applied Sciences at Harvard University. He continues to develop technologies around the unique properties of polymeric nanofibers and nonwoven materials and to study the behavior of polymeric materials through molecular simulations and experiments. He serves as editor or editorial board member for the journals *Polymer*, *Macromolecules*, and *Journal of Engineered Fibers and Fabrics*. He co-organized a second, very successful symposium on "Polymer Nanofibers: Fundamental Studies and Emerging Applications" at the Materials Research Society meeting in Boston and delivered invited lectures at conferences and industry on topics of multiscale modeling, molecular simulation of polymers, electrospinning, and nanofibers. Professor Rutledge also serves on the faculty selection committee for the professor of multiscale materials modeling at ETH Zurich.

Hadley D. Sikes joined the department in fall 2009 as the Joseph R. Mares assistant professor of chemical engineering. Her research focus is the engineering of biological molecules for technological purposes in the field of biomedicine with an emphasis on quantitative, mechanistic experimental approaches. She received a Burroughs Wellcome Fund Career Award at the Scientific Interface.

Professor George Stephanopoulos received the 2009 John R. Ragazzini Award of the American Automatic Control Council for "outstanding contributions in process control and systems engineering education through classroom teaching, textbook and monograph publication, and graduate student mentorship;" he was also selected for the 2009 Aurel Stodola Medal and Lecturership at ETH Zurich. He presented the Institute of Chemical Engineering and High Temperature Chemical Processes 25th Anniversary Lecture, in Patras, Greece; the 2010 Wilhelm Lectures at Princeton University; the 2010 Ruckenstein Lecture at University of Buffalo; and the 2010 L.T. Fan Lecture at Kansas State University. He also delivered invited lectures at Foundations of Computer-Aided Process Design 2009 and Process Systems Engineering 2009.

As director of the Bioinformatics and Metabolic Engineering Laboratory, professor Gregory N. Stephanopoulos continued his research in metabolic engineering with increased emphasis on the engineering of microbes for biosynthesis of biofuels and biobased products. Technologies developed in the course of this research are critical for advancement of a bio-based economy. Professor Stephanopoulos continued his service on the advisory boards of four academic institutions and as chair of the managing board of the Society for Biological Engineers, which promotes the integration of biology and engineering to provide enabling technologies for industrial and medical applications. He delivered the 2009 Ashland Distinguished Lecture and McFerrin Distinguished Lecture at the University of Kentucky and Texas A&M University, respectively. In 2010, he was the Pigford distinguished lecturer at the University of Delaware. He continued to serve as editor-in-chief of the journal *Metabolic Engineering*, published by Elsevier, and on the editorial boards of seven other scientific journals. Besides numerous research presentations at professional society meetings (AIChE, ACS, American Society for Microbiology), he also delivered plenary and keynote lectures at the 17th Biochemical Engineering Conference, TMFB Conference (Aachen, Germany), NRC Report on Renewable Fuels (Annual AIChE Meeting), 14th European Congress on Biotechnology (Barcelona), ACS Annual Meeting (San Francisco), IEEE Conference on Bioinformatics and Biotechnology, 4th China Bioindustry Convention (Jinan, People's Republic of China), and 8th Conference on Metabolic Engineering. During this year professor Greg Stephanopoulos was honored with the E.V. Murphree Award in industrial and engineering chemistry of ACS and the HBA-USA Aristoteles Award.

Professor Michael S. Strano has continued his research focusing on the chemical engineering of low-dimensional systems. After receiving tenure in July 2009, he was awarded the 2009 Ernest Thiele lectureship from Notre Dame University and the 2009 Robert M. Langer lectureship from Yale University, and he was named one of the Brilliant 10 by *Popular Science Magazine*. His work on the theory and discovery of thermopower waves—a new mechanism for energy conversion along a thermally conductive nanorod—was published in *Nature Materials* in March and received coverage from CNN, BBC radio, and a video segment filmed by the Discovery Channel in his laboratory. He is the lead principal investigator on a multi-university effort that includes MIT, Harvard, and Boston University to advance graphene electronics. His work on a new analytical platform for studying cell signaling was published in *Nature Nanotechnology* and featured in Physorg, cnet, and *Tech Review*. Michael gave 13 invited lectures, published 18 peer-reviewed journal publications, and filed for 8 patents within the past year.

In January 2009, professor Jefferson W. Tester transitioned to emeritus status when he assumed a new position as the Croll professor of sustainable energy systems at Cornell University. Professor Tester continued to collaborate on a number of research projects on renewable energy technologies with increasing emphasis on hybridization of geothermal, solar, and biomass energy supply systems for electricity, district heating, and cogeneration applications. His research work focused on hydrothermal conversion and upgrading a range of biomass and unconventional fossil fuels and advanced drilling technology using thermal spallation methods. This past year, Professor Tester continued a heavy speaking schedule, giving invited lectures on geothermal and biomass energy at Georgia Tech, Notre Dame, Colorado School of Mines, United States Military Academy (West Point), University of Michigan, the World Energy Council, and BP. Professor Tester entered his second year as the US representative on geothermal energy for the Intergovernmental Panel on Climate Change's Special Report on Renewable Energy and Climate Change Mitigation. He also continued his advisory roles for the National Renewable Energy Laboratory, Idaho National Laboratory, Los Alamos National Laboratory, and the Midwest Research Institute.

Professor Bernhardt L. Trout continues in his roles as director of the Novartis–MIT Center for Continuous Manufacturing, a $65 million collaborative project focusing on transforming pharmaceutical manufacturing, and co-chair of the SMA program on chemical and pharmaceutical engineering. He also runs a laboratory of 25 graduate students and postdocs focusing on pharmaceutical small-molecule manufacturing and biopharmaceutical formulation and stabilization. He set up the MIT–Benjamin Franklin Project for the Advancement of the Arts and Sciences, a project to enhance engineering and scientific education and is director of the freshman-year Concourse Program. He presented more than 10 invited talks.

Professor Daniel I.C. Wang continues to participate in the SMA program. He attended and presented papers at the 2010 SMA annual symposium in Singapore. He also participated in the SMA course Chemical Reaction Engineering" by lecturing in Singapore in August 2009. Professor Wang continues to be an active member in the MIT Portugal Program, performing collaborative research and lecturing in the bioprocess engineering module at the New University of Lisbon in September 2009. Professor Wang was chairman of the scientific advisory board for the A*STAR Bioprocess Technology Institute and attended its annual meeting in Singapore in March 2010. Lastly, Professor Wang was bestowed the Singapore Service Medal presented to him by the president of Singapore in November 2009 and was awarded an honorary doctorate degree at the New University of Lisbon in April 2010 in Lisbon, Portugal.

Research Highlights

Integrated Single-Cell Analysis for Immune Profiling (J. Christopher Love)

The immune system is a multicellular network that plays a central role in many human diseases, either as a protagonist protecting us from infectious diseases or as an antagonist attacking our own tissue in autoimmune and inflammatory diseases. Understanding how the immune system reacts in specific diseases to resolve or exacerbate a patient's condition requires evaluating the types and functions of the various cells involved.

A range of analytical technologies, including flow cytometry, enzyme-linked immunospot assays, and microarrays for detecting DNA or RNA, are available to characterize immune cells isolated from blood or tissues of patients. These technologies are sufficient for assessing some aspects of the phenotypic and functional diversity within a population of cells. For example, one can determine the number of certain types of cells, like T or B cells, or the percentage of cells secreting a certain protein. Each technology is well suited to ask a particular question or related set of questions about the cells, but characterizing multiple attributes requires many independent assays. Conducting a comprehensive analysis involving multiple assays for a given sample is difficult, therefore, when cells of particular interest are rare or the number of cells is limited (for example, a tissue biopsy can often yield only 10,000 to 100,000 cells).

To address this challenge, Professor Love's group is developing a new approach—termed integrated single-cell analysis (iSCA)—to evaluate the diversity among populations of cells. The approach allows quantitative characterization of multiple attributes for many individual cells in parallel—even when the numbers of cells are extremely limited (~10,000). Microfabricated arrays containing ~100,000 subnanoliter wells provide a platform to isolate and analyze single cells to determine multiple attributes of each one, including the types of cells present, their functional activities (secretion of cytokines or antibodies, proliferative capacity, cytolytic activity), and expression of certain genes (Figure 1). Analytical operations using this array are modular by design and can be performed in series or in parallel.

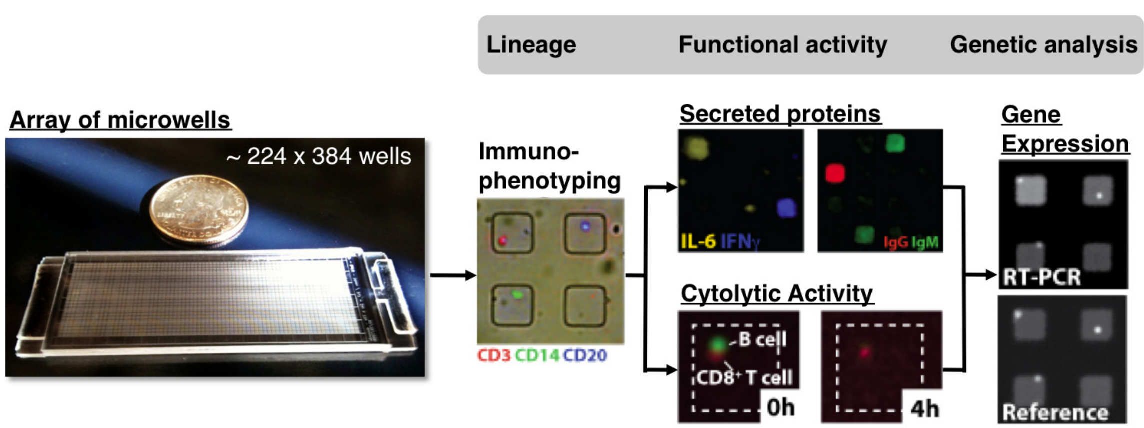

Figure 1. Schematic illustration of an analytical platform for integrated single-cell analysis (iSCA). The fabricated microsystem on the left can isolate up to ~85,000 cells. This platform can be used for a number of modular processes to measure the identities of cells, their functional behaviors, and gene expression. Examples of data generated by these operations are shown on the right.

One particular analytical process, called microengraving, produces microarrays of proteins captured from the cells isolated in the array of microwells. Based on intaglio printing, the method uses the array of microwells containing cells as an engraving plate to print a spatially registered microarray of antibodies or cytokines (*Nature Protocols* 2009). Analytical modeling of this process has defined operational conditions that allow quantitative assessments of the rates of secretion for up to four or five proteins simultaneously from single immune cells (*Lab on a Chip* 2010). Modification of the surface of the microwells with specific proteins enables on-chip activation of certain T cells that are sensitive to particular peptides derived from pathogens or autoantigens (*Analytical Chemistry* 2010). Since the process is nondestructive, the cells can be recovered afterward by micromanipulation. This feature makes it possible for the first time to identify immune cells on the basis of their functional responses for further analysis in vitro.

Another modular operation developed by the group allows massively parallel measurements to detect the presence of particular expressed genes for thousands of cells at a time (*Lab on a Chip* 2010). Using the same array of microwells employed in microengraving, it is possible to perform individual polymerase chain reactions in each well to detect the expression of one or more genes (Figure 1, right panel). Further development of this method should allow the detection of cells harboring replicating intracellular pathogens such as HIV, endogenous retroviruses, and tuberculosis. Because the array of microwells represents a common platform, it is possible to integrate this method with other modular processes such as microengraving. This integration permits direct assessments of the relationship between different biological functions such as transcription and secretion with single-cell resolution.

With the collection of modular processes developed to date, the Love lab is now pursuing research focused on profiling the cellular immune response in chronic human diseases such as HIV/AIDS, multiple sclerosis, and food allergies. These studies could facilitate the development of new immunotherapies and vaccines and improve immunological monitoring of the progression of diseases and the efficacy of immunotherapies over time. Using analytical microsystems to generate multiplexed, quantitative data with single-cell resolution, iSCA should also enhance the development of a new field focused on quantitative systems immunology.

The Love lab's approach to analyzing immune responses in human diseases by iSCA is also applicable in other areas of research where cellular systems are important. For example, the same analytical techniques can assess the single-cell productivity of microbial cultures used for manufacturing protein-based pharmaceuticals and may provide new process analytical technologies for monitoring bioreactors used in industry (*Biotechnology and Bioengineering* 2010). These examples, taken together, highlight how applying principles from chemical engineering to advance bioanalytical technologies will address several current challenges in the areas of diagnosis and treatment of disease as well as the manufacturing of therapies.

Gene Switches Rely on "Bursty" Gene Expression (Narendra Maheshri)

The Maheshri lab is interested in understanding the dynamics of eukaryotic gene regulation to the extent that it will enable predictive models and engineering of larger gene regulatory networks and augment mechanistic descriptions of gene expression. One important job of signaling and genetic regulatory networks in cells is to make clear-cut decisions to commit to one or another expression program in response to an external signal. Clear decisions are crucial in development, where the choice of cell fate must be unambiguous. They are also important in pathogenesis, where an infecting virus must decide whether to lie low within a cell or hijack cellular machinery and make more copies of itself.

A particular pattern, or motif, in gene regulatory networks associated with decision making is the positive feedback loop (Figure 2). In a common example, a transcriptional activator activates its own expression. A signal that triggers the positive feedback results in high levels of activator—a switch from an "off" to an "on" expression state. Because of this switch-like response, at intermediate levels of signal, individual cells have either high or low levels of activator but never intermediate levels. Hence, the distribution of expression levels within a population of cells is bimodal. However, previous theoretical and experimental work suggested that this switch-like response required that the dose–response curve of the activator's promoter in the absence of feedback to the activator (i.e., the open-loop response) should be S-shaped—unresponsive at low levels of activator and then abruptly more responsive at high levels of activator. The theoretical explanation is that the dynamical system describing the positive feedback loop can be bistable, which means both the "on" and "off" expression states can simultaneously be stable and each individual cell sits in one of these states.

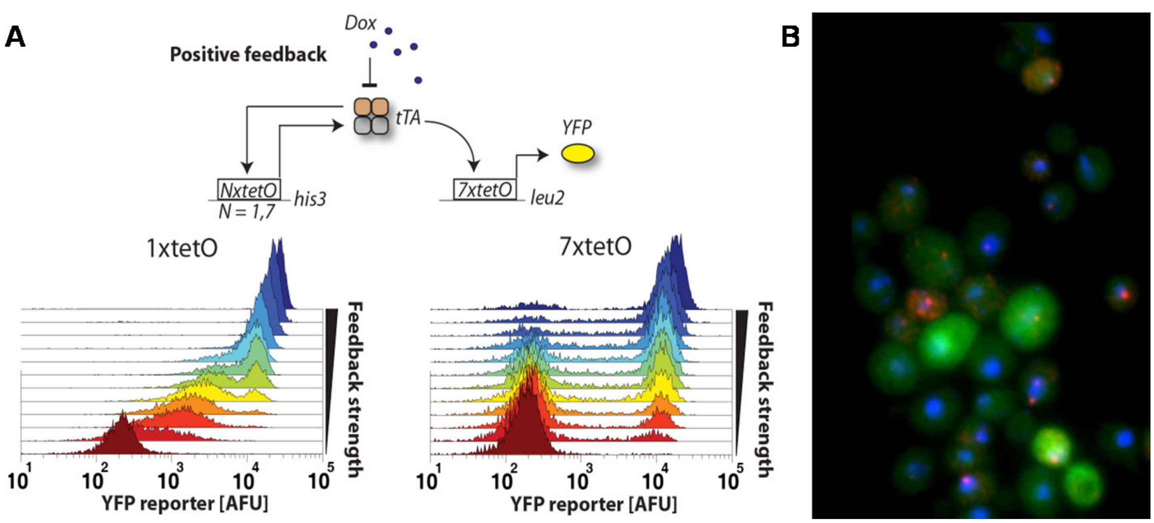

Figure 2 (A). The state of a transcriptional positive feedback loop in single cells was monitored via expression of a yellow fluorescent reporter protein. Feedback strength was modulated by addition of a small molecule (dox), which inhibits the transcriptional activator (top). Histograms of YFP expression (bottom) show a graded or bimodal, switch-like response depending on the number of binding sites in the promoter. Figure 2 (B). mRNA (stained red) expressed from the 7xtetO promoter was monitored in single yeast cells. The wide distribution is indicative of bursty expression (blue, nucleus; green, YFP).

In a recent study (*Science* 2010), the Maheshri lab observed that a positive feedback loop with a promoter containing repeated binding sites is associated with a bimodal response. The commonly held reason for this response is that repeated binding sites in the promoter lead to cooperative binding of a transcription factor to the promoter, leading to an S-shaped dose–response curve and hence a bistable system. However, here they prove that the dose–response curve of the promoter is linear, not S-shaped, and go on to show that the reason why the response remains bimodal is because of noise in gene expression—specifically, the intermittent and random nature of transcription. It turns out multiple binding sites result in infrequent but large bursts of transcription, whereas a single binding site results in more frequent but smaller bursts of transcription. A stochastic model of gene expression can explain why infrequent but large bursts of transcription are crucial for bimodal expression. A large burst can trigger the feedback loop "on," but if the activator is unstable, there is some chance that all activators will degrade before the next (infrequent) burst of expression occurs, turning the feedback loop "off."

Because positive feedback loops are prevalent in biology, many promoters have repeated binding sites, and transcription factors are often unstable, "bursty" transcription may actually underlie many decision-making processes in cells rather than bistability. The study also highlights an emerging theme of how noisy, random processes in biology can produce regular behavior in the system in which they are embedded. The lab is now trying to understand what features of eukaryotic promoters, such as binding site number, affinity, and chromatin structure, dictate the "burstiness" and hence dynamics of transcription. This dynamic information can complement classic biochemical and genetic approaches to provide a richer view of transcriptional regulation.

Annual Lectures, Seminars, and Symposia

During 2009–2010, the Chemical Engineering Department hosted a distinguished group of academic and industry leaders; highlights are noted below. Webcasts for all Chemical Engineering major lectures can be accessed at http://web.mit.edu/cheme/news/webcast.html.

24th Hoyt C. Hottel Lecture (Dec 4, 2009): "Membranes: The Vanguard of Large Scale Low Energy Intensity Separations." William J. Koros of Georgia Tech discussed the evolution of large-scale membrane processes, including future steps toward revolutionizing the "separation landscape." Professor Koros is an advocate for technology-assisted strategies to reduce the energy intensity and carbon dioxide footprints of chemical processes.

16th Alan S. Michaels Lecture (April 2, 2010): "Starting and Building Biotech Companies: From Sepracor to Selecta." Robert L. Bratzler is executive chairman of Selecta Biosciences, a Watertown-based biotech company pioneering the development of targeted nanoparticle vaccines for treatment and prevention of diseases. Dr. Bratzler, an alumnus of the Chemical Engineering Department, shared advice and anecdotes from his experience of starting several successful biotechnology companies.

32nd Warren K. Lewis Lecture (April 30, 2010): "The Untold Story of Gluten: Viscoelastic Wonder, Rat Poison, or Autoimmunity's Rosetta Stone?" Chaitan

Khosla of Stanford University presented issues surrounding the "fascinating material" gluten and celiac disease. Over the past two decades Professor Khosla has studied polyketide synthases as paradigms for modular catalysis and has exploited their properties for engineering novel antibiotics. More recently, he has investigated celiac sprue pathogenesis with the goal of developing therapies for this widespread but overlooked disease.

Symposium to honor professor emeritus Edward W. Merrill (May 14, 2010): Edward W. Merrill is a pioneer in the field of biomedical engineering. The Chemical Engineering Department celebrated his six decades of research and teaching excellence (Figure 3). Speakers included former students, colleagues, and current researchers who today continue to build upon his legacy of work in polymer synthesis, physical chemistry, and biomaterials.

Figure 3. Attendees at the May 14 symposium to honor professor emeritus Edward W. Merrill (including Professor Merrill, right center) react to anecdote by professor Clark K. Colton.

Departmental Awards

The department awards ceremony took place on May 10, 2010, in the Gilliland Auditorium of the Ralph Landau Building. We are pleased to recognize this year's recipients of the Outstanding Faculty Awards: Professor William M. Deen was the graduate students' choice and professor Barry S. Johnston was selected by the undergraduate students.

The Edward W. Merrill Outstanding Teaching Assistant Award was presented to graduate student Vikramaditya Yadav for his work in 10.37 Chemical Kinetics and Reactor Design. The Outstanding Graduate Teaching Assistant Award was presented to Diwakar Shukla for his service to 10.50 Analysis of Transport Phenomena.

Chemical Engineering Special Service Awards were conferred to the members of the Graduate Student Council: Matthew Blackburn, Caroline Chopko, Rachel Howden, Jen Lee, Cheri Li, Kevin Lin, Jeffrey Mo, Asha Parekh, Christy Petruczok, Spencer Schaber, Armon Sharei, Karthik Shekhar, Mike Stern, and Achim Wechsung. In addition, Joshua Allen was awarded the Chemical Engineering Rock for outstanding athleticism and Katrina Westerhof was recognized for her year as president of the student chapter of AIChE. All third-year graduate students are required to present a seminar on the progress of their research, and the two recipients of the award for outstanding seminar were Chris Marton and Stephen Chapin.

Our undergraduates also earned numerous accolades over the course of the year. As one of MIT's scholar athletes, Jeffrey Zhou received the Malcom G. Kispert Award. Rachel Licht won a Fulbright Scholarship to research cellulosic ethanol in France.

Timothy Humpton was the recipient of the Gates Cambridge Scholarship for 2010. The National Goldwater Scholarship was presented to Allen Lin for his devotion to science. The Genetech Scholar Award recognizes outstanding students in disciplines related to production and development and was presented to Amrita Karambelkar. The Merck Fellowship was presented to Grace Liao in recognition of her scholastic excellence. The Robert T. Haslam Cup, which recognizes outstanding professional promise in chemical engineering, went to Gregory Johnson. The department's oldest prize, the Roger de Friez Hunneman Prize, is awarded to the undergraduate who has demonstrated outstanding achievement in both scholarship and research; this year it went to Mary Jane Tsang Mui Ching.

The department is quite pleased to recognize Christine Preston as its outstanding employee of the year for her dedication and exceptional service to faculty, staff, and students. Employee Teri Chung, financial coordinator for the administrative services organization, was presented with this year's Chemical Engineering Individual Accomplishment Award for her contribution to the October 2008 steam-pipe incident recovery. Also for 2010, Lisa Fitzpatrick, Gregory Stephanopoulos, and Beth Tuths joined MIT's Quarter Century Club for their 25 years of service to MIT.

The Department of Chemical Engineering at MIT has certainly had a very fruitful and rewarding year and is poised for even bigger and greater successes for the upcoming year.

Klavs F. Jensen
Department Head
Warren K. Lewis Professor of Chemical Engineering

Paula T. Hammond
Executive Officer
Bayer Professor of Chemical Engineering

More information about the Department of Chemical Engineering can be found at http://web.mit.edu/cheme/index.html.