Department of Chemical Engineering

For the 2009 academic year, the Chemical Engineering Department continued to lead the field in several key research areas, from energy and the environment to pharmaceutical manufacturing and biomedical engineering. The department's commitment to excellence in teaching and research was recognized by its number one ranking in *US News and World Report* in both undergraduate and graduate programs for the 20th year in a row. Despite the dramatic economic downturn during this past fiscal year, sponsored research funding increased for chemical engineering faculty; sponsored research expenditures for FY2009 were $41.2 million, an increase of more than 20% from the previous year. It is also notable that a significant portion of research dollars represents increased engagement of the faculty in energy- and environment-related projects, including the MIT Energy Initiative (MITEI). Department involvement in MITEI is very strong: MITEI-funded research projects involve professors Robert Armstrong (also MITEI deputy director), Karen Gleason, Paula Hammond, Alan Hatton, Klavs Jensen, Greg McRae, and Michael Strano; several additional faculty members have been engaged in other MITEI activities. In the biomedical area, professors Arup Chakraborty and Christopher Love have been involved in the generation of a new research center, the Ragon Institute, which was founded with a $100 million, 10-year grant from the Phillip T. and Susan M. Ragon Institute Foundation to address the development of HIV vaccines.

Professor Klavs F. Jensen recently completed his second year as department head and has been working on long-term goals that include continued growth and infrastructure for the department while working closely with the administration during the recent economic challenges faced by the nation and the Institute. Professor Paula T. Hammond is completing her first year as executive officer after taking on the role in August 2008, and is preparing to focus on various aspects of the undergraduate program in the upcoming year. The relatively new department administration faced challenges in handling a significant steam explosion that took place in the subbasement of Building 66 in October 2008, as well as experiencing the strength, patience, and flexibility of faculty, staff, and students during recovery from this event. Professor William M. Deen remains the department's graduate officer while Barry Johnston continues to serve as undergraduate officer. Professor Arup Chakraborty completed a very successful recruiting effort in his second year as the graduate admissions chair, gaining a high yield from a very selective group of admitted students. The department remains honored to have two Institute Professors as key department members: Daniel C. Wang and Robert S. Langer. This academic year we are celebrating the promotion of professor Michael S. Strano to associate professor with tenure. We are very pleased to welcome professor Martin Bazant, who joined the department as an associate professor with tenure in spring term 2009 following a faculty appointment in the Mathematics Department at MIT. The department also welcomed new support staff members Bethany Day, Valerie Grimm, Fran Miles, and Christine Preston. New hires to the Administrative Services Organization included Teri Chung as administrative staff and Christine Rodriguez and Phoebe Spence as support staff.

We had a very successful recruiting season, with Hadley Sikes accepting a position as an assistant professor. Professor Sikes plans to join the department in August 2009 after completing her postdoctoral stay with Frances Arnold at Caltech this summer. She held the National Institutes of Health National Research Service postdoctoral award (while working with Chris Bowman at the University of Colorado) and, most recently, the Burroughs–Wellcome Fund Career Award, which has enabled her to launch her own independent research program while at Caltech and extends funding into her early years as a faculty member. Professor Sikes' current research interests include the development of engineered enzymes using directed evolution that generates superoxides as a means of cancer remediation. This year also marks the arrival of professor Jesse Kroll, who is a junior faculty member in the Department of Civil and Environmental Engineering with a joint position in Chemical Engineering. Professor Kroll's research interests include environmental and atmospheric chemistry, and he is pursuing the development of new analytical tools for the characterization of atmospheric organics.

National recognitions and achievements among the faculty include the induction of professor Robert Armstrong into the National Academy of Engineering and professor Klavs Jensen into the American Academy of Arts and Science, as well as the election of professor Arup Chakraborty to the American Association for the Advancement of Science. Professor Robert Langer received the American Institute of Chemical Engineering (AIChE) Founders Award, and professor Michael Strano received the AIChE Allan P. Colburn Award and the 2008 Outstanding Young Investigator Award from the Materials Research Society. Professor Patrick Doyle received the prestigious 2009 Guggenheim Fellowship for his work on soft functional microparticles generated with microfluidics and also won the Lab on a Chip/Corning Inc. Pioneers of Miniaturisation Prize in fall 2008. At AIChE's centennial meeting, 50 chemical engineers were identified as "Chemical Engineers of the Foundation Age"; 17 of them were MIT faculty or alumni. Of the 100 chemical engineers selected as "Chemical Engineers of the Modern Age," 24 were MIT faculty, former faculty, or alumni. No other department was as well represented. The current faculty members honored included professors Clark Colton, Klavs Jensen, Edward Merrill, Bob Langer, Charles Satterfield, and George Stephanopoulos.

Among the many news items related to research in the department, professor Kristala Jones Prather provided an analysis of biotechnology and synthetic biology as a means of generating future cancer drugs and their precursors. The synthesis of natural and unnatural plant alkaloids using a bottom-up approach to genetically engineering biological pathways of plant cells is discussed in her recent *Nature Chemical Biology* review. Professor Dane Wittrup and coworkers discovered that antibodies can be generated without the presence of a specific sugar attachment that only mammalian cells can generate and maintain their therapeutic efficacy. Because the conventional understanding of antibodies was that this sugar attachment was needed for the efficacy of antibodies to bind to immune cells, antibody treatments for cancer and numerous other diseases were prohibitive in cost due to difficulties in synthesis based on mammalian cell culture. In a *Proceedings of the National Academy of Sciences* article, Wittrup demonstrated that a mutant form of the antibody could be generated without the sugar while maintaining antibody activity, thus opening the pathway to much more accessible antibody therapeutics. Finally, a new method of protein printing from microscale cellular arrays was developed by professor Christopher Love as a means of determining antibody expression in a rapid assay that generates information about immune response to vaccination treatments. The new approach uses a small drop of blood to complete an analysis that would ordinarily require three separate tests and large amounts of blood, yielding the number of immunological cells, number and type of antibodies produced, and antibody affinity and specificity for a specific target antigen; this work was published in the *Proceedings of the National Academy of Sciences*.

With regard to outreach to our alumni and the public, the department introduced a new and completely revamped website this past year, with highlights and features from faculty and students and special brief comments from some of the newest alumni of the department's graduate program featured on the home page. The Chemical Engineering Department also featured its first alumni appreciation dinner as a means of connecting with key alumni and friends of the department this past fall.

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, 75 SB degrees were conferred as of June 2009, with 55% awarded to women. Student quality remains excellent. The distribution of undergraduate students by class over the last 10 years is shown in Table 1.

Table 1. Undergraduate Enrollment over the Last 10 Years

Class year	99–00	00–01	01–02	02–03	03–04	04–05	05–06	06–07	07-08	08-09
Sophomores	71	67	47	56	56	95	100	95	96	87
Juniors	85	76	66	49	43	55	83	75	67	77
Seniors	103	89	84	65	41	55	53	83	77	75
Total	259	**232**	**197**	**170**	**140**	**205**	**236**	**253**	**240**	**239**

The Course 10-B program leading to the 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 subjects in biochemistry, genetics, and cell biology; (2) a core in engineering science comprising subjects in 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 from the outset, with undergraduate enrollment rising from 20 students in 2004 to 105 in 2006, 150 in 2007, 143 in 2008, and 131 in 2009. Currently, students in the chemical-biological engineering program constitute 55% of the undergraduates in the Department of Chemical Engineering. Thirty-nine seniors graduated with degrees in chemical-biological engineering in the Class of 2009, and 49 freshmen in the Class of 2012 declared majors in chemical-biological engineering.

The average starting salary for graduates of the Department of Chemical Engineering is $63,256 (2009 senior survey), which is among the highest in the School of Engineering. This attests to the success of the graduates of the Course 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 Kathryn Schumacher (president), Kirtana Raja (vice president), Mindy Du (secretary), Maria Duaime (treasurer), Lisa Wang (Class of '09 representative), Katrina Westerhof (Class of '10 representative), and Apiradee Sanglimsuwan (Class of '11 representative).

In 2007–2008 the department's undergraduate programs came up for accreditation by the Accreditation Board for Engineering and Technology, as part of a School-wide review of programs in engineering, which occurs every seven years. The SB degree program in chemical engineering (Course 10) achieved re-accreditation in 2008, and the new SB degree program in chemical-biological engineering (Course 10B) has now become the first accredited dual-name degree in both chemical engineering and biological engineering. Thanks to the efforts of Gregory Rutledge, who completed his term as executive officer in summer 2008, and Barry Johnston, our department is accredited for a full six-year period as of 2008.

Graduate Education

The graduate program in the Department of Chemical Engineering offers (SM) degrees in chemical engineering and in chemical engineering practice (MSCEP), the Doctor of Philosophy (PhD) and Doctor of Science (ScD) degrees in chemical engineering, and a PhD degree 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 260, with 228 in the doctoral program and 32 master-level degree candidates. In the doctoral program, 211 students are in the PhD/ScD track and 17 are in the PhDCEP track. In the master-level program, 22 are in the MSCEP track. Of our graduate students, 29% are women and 2% are underrepresented minority students. Forty-six of our graduate students received outside fellowship awards, including those from the National Science Foundation, National Institutes of Health, Department of Defense, and others. The distribution of graduate students by degree is shown in Table 2 for the last 10 years. During the 2009 academic year, 43 doctoral degrees (39 PhD or ScD, 4 PhDCEP) were awarded, along with 49 master-level degrees (43 MSCEP, 6 SM) for a total of 92 advanced degrees conferred. Forty-four students passed the doctoral qualifying exams and were promoted to candidacy for the PhD/ScD or PhDCEP. The department received 349 applications for admission to

Table 2. Graduate Enrollment over the Last 10 Years

Degree level	99-00	00–01	01–02	02–03	03–04	04–05	05–06	06–07	07-08	08-09
Master's	54	40	38	36	26	19	16	18	26	32
Doctoral	145	166	209	245	232	216	203	217	212	228
Total	**199**	**206**	**247**	**281**	**258**	**235**	**219**	**235**	**238**	**260**

the doctoral program, offered admission to 44 individuals, and received 31 acceptances of offers, for an acceptance percentage of 70%. Of 89 applications for master-level degrees, the department made 22 offers and received 16 acceptances of offers, for a yield of 73%. Among the incoming graduate class for 2009, 12 are women and 1 is an underrepresented minority. On average, the incoming graduate class held an undergraduate grade point average of 4.95 (out of 5.0).

Research Centers

The Department of Chemical Engineering is actively involved and takes a leadership role in several MIT-wide education and research programs. A few of them 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 third year on June 30, 2009. Professor Bernhardt Trout is cochair of this program with professor Raj Rajagopalan of the National University of Singapore. There are currently 56 students in the program, 26 dual master's 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 Doyle, Alan Hatton, Kenneth Smith, Gregory Stephanopoulos, Bernhardt Trout, and Daniel Wang.

DuPont–MIT Alliance

The DuPont–MIT Alliance (DMA), renewed on January 2005 for a second five years with an award of $25 million, has been extended through December 2011. Because of the economic climate, the award this year was $1.5 million.

The current steering committee members, who are responsible for the direction of research and educational activities, include director Claude Canizares, vice president for research and associate provost; associate director Robert E. Cohen, St. Laurent professor of chemical engineering; and steering committee member Bruce Tidor, professor of biological engineering and computer science.

The interrelationship of research and education underlies the success of DMA and is acknowledged through DMA's support of 139 graduate students who were named as DuPont Presidential Fellows at MIT. After their first year, these graduate students were supported by the funded research programs of their faculty thesis advisors. In the 2008–2009 academic year, 10 fellows were named in the Departments of Biology, Biological

Engineering, Chemistry, Chemical Engineering, Materials Science and Engineering, Mechanical Engineering, Electrical Engineering and Computer Science, Physics, Sloan School of Management, and the Program in Polymer Science and Technology.

The education thrust promotes participation at the investigator level as well. This coming academic year 2009, five fellowships will be awarded to newly hired associate professors to assist in their research programs.

On the research activity side of DMA, the selection of proposals begins with a review of white papers and proposal submission from both a campus-wide solicited call as well as a year-round acceptance of white papers from faculty on various topics of interest to DMA. The portfolio of projects is reviewed and revised annually by the steering committee. Fifty-five projects have been sponsored, and each has had a DuPont liaison. The close relationship of DuPont and MIT is fostered through this multidisciplinary team effort in the research program and by semiannual symposia presented alternatively by principal investigators as well as graduate students and postdoctoral associates. This year, as a cost-saving measure, the fall research symposium was presented via video conference.

At present there are 11 research projects under the direction of professors Daniel Blankschtein, Gerbrand Ceder, Leon Glicksman, Alan Hatton, Robert Langer, Greg Rutledge, Francesco Stellacci, Michael Strano, Bruce Tidor, and Krystyn Van Vliet. These funds support six Undergraduate Research Opportunities Program students, nine graduate students, and seven postdocs. DMA has sponsored 32 patent applications.

As the alliance grows, 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.

Department and Novartis–MIT Center Introduce New Dedicated Facility

Now in its second year, the Novartis–MIT Center for Continuous Manufacturing is taking academic pharmaceutical research to a new level with construction of a dedicated facility that will aid the center in its goal of revolutionizing pharmaceutical manufacturing. Currently, pharmaceutical manufacturing is performed in batch mode, in which each step of a manufacturing process is physically separated from the other steps. On the other hand, continuous processing, in which materials flow uninterrupted through the process, offers the potential for leaner processing, higher quality, more flexibility, and, in the end, costs savings. The $5.2 million laboratory, jointly funded by Novartis and MIT, will be capable of handling all but the most hazardous pharmaceutical compounds and will consist of a wet chemistry, an analytical, a powder-handling, and a bench-scale continuous manufacturing line area. The design of the facility is in keeping with the collaborative and integrative nature of the project, as housing all these areas under one roof allows for the continuous pharmaceutical process research to take place alongside development of the prototype bench-scale unit. Unique to the Institute, the facility will provide students with research opportunities previously not found outside of industry. The facility is located on the second floor of the Landau Building, in an area that is central to the department's research and teaching activities (Figure 1). The building project represents one of the most significant dedications to space in the department for a major research program and indicates the level of commitment around the formation of this unique capability. Slated to open in October 2009, this state-of-the-art facility will place MIT at the forefront of pharmaceutical manufacturing technology research and innovation for many years to come.

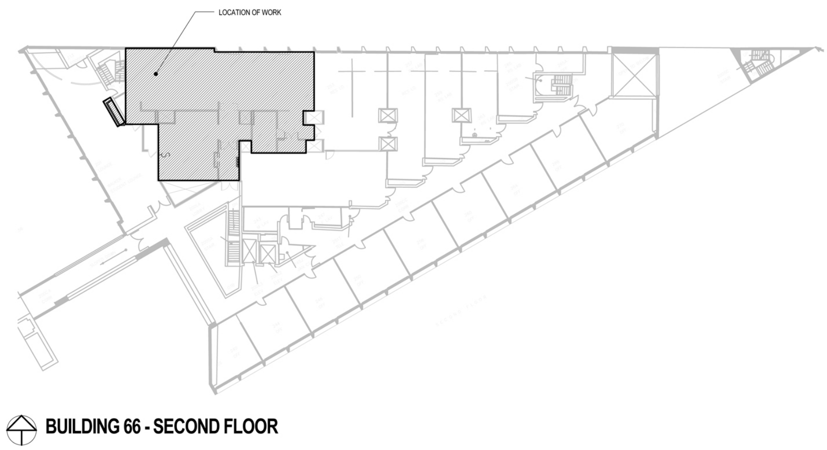

Figure 1. The grey shaded area of the floor plan indicates where the new Novartis/ MIT facility will be located in the Ralph Landau Building.

The center is led by Bernhardt L. Trout, MIT center director and professor of chemical engineering, and Walter Bisson, Novartis manager. In addition, the team consists of James Evans, MIT associate director; Stephanie Bright, MIT program coordinator; 12 staff members from Novartis; 11 MIT professors; and 40 MIT graduate students and postdocs. Notably, professor Allan Myerson of the Illinois Institute of Technology has joined the center to assist in the development of continuous crystallization processes, and Dr. Salvatore Mascia of Cambridge University has been hired to build the prototype bench-scale unit.

Faculty Notes

Professor Robert C. Armstrong served as deputy director of MITEI and worked with the director, Ernest Moniz, in launching the research, educational, campus, and outreach components of the initiative over its first two years of operation. Thirteen companies and public institutions were recruited to sponsor research as founding and sustaining members of MITEI. MITEI has raised more than $250 million in research support over its first two years of operation; some 40 energy graduate fellowships are supported each year by MITEI sponsors. This year, Professor Armstrong was inducted into the National Academy of Engineering. During this past academic year he gave the L.T. Fan Distinguished Lecture at Kansas State University and a keynote lecture on energy at the Politecnico di Torino. He chaired the energy advisory board for the City University of Hong Kong and serves on the advisory boards of chemical engineering departments at Georgia Tech, the National University of Singapore, Northwestern University, Texas A&M University, the University of Washington, and the University of Tennessee.

After spending fall 2008 as tenured faculty at Stanford University's Mechanical Engineering Department, professor Martin Z. Bazant joined the Chemical Engineering Department at MIT in December 2008, with a courtesy appointment in Mathematics. He continued his theoretical research in electrokinetics, electrochemistry, and microfluidics and plans to start an experimental laboratory. He published a new mathematical theory of Li-ion batteries, which predicts nonlinear waves of Li intercalation moving layer by layer along a crystal surface (rather than by diffusion into the bulk), consistent with experiments on $LiFePO_4$. He designed a graduate subject Course 10.626 Electrochemical Energy Systems, offered as Course 10.95/18.325 in spring 2009 and listed with MITEI. He returned to coaching undergraduates in the mathematical contest in modeling, and two MIT teams won the meritorious ranking (top 5% of more than 1,000 teams worldwide).

János M. Beér continued his membership on the US National Coal Council, Advisory Committee to the US Secretary of Energy, and coauthored the Council's 2008 Report to the Secretary. He chaired the keynote panel at the 34th International Technical Conference on Clean Coal and Fuel Systems in Clearwater, FL, in May 2009 entitled "New and Existing Power Plants before the Advent of Commercial Carbon Capture and Storage." He also presented the keynote lecture "Fossil Energy Electric Power Generation in a Carbon Constrained World" at the International Flame Research Foundation's conference in Boston in June 2009.

Professor Daniel Blankschtein's research group conducted fundamental theoretical research as well as 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 2008 and the interdisciplinary graduate subject 10.43 Introduction to Interfacial Phenomena in spring 2009. Professor Blankschtein and his students delivered talks at the 2008 AIChE Annual Meeting, at the 17th International Symposium on "Surfactants in Solution" in Berlin, Germany, and at the DMA Faculty Symposium held at MIT in May 2009. Professor Blankschtein is a member of the editorial board of Marcel Dekker's *Surfactant Science Series*.

Robert T. Haslam professor Arup K. Chakraborty experienced one of the most productive years in his academic career. In research, he brought together statistical mechanical approaches with experimental tests (carried out by professor Art Weiss at the University of California, San Francisco). They discovered the molecular mechanism that enables the signaling machinery in T cells to be "on" or "off." The same machinery that allows digital signaling confers T cells' short-term molecular memory of past encounters with antigen. These findings were published in *Cell*. They also shed light on a long-standing problem in immunology—T cell recognition of antigen is both exquisitely specific and degenerate. An analogy with spin–glass physics has allowed them to elucidate how a T cell repertoire with these characteristics is designed during development. These results were published in *Proceedings of the National Academy of Sciences*, and current research suggests that it may have deep implications for a particular aspect of the immune response to HIV. He published numerous other articles. Professor Chakraborty led the MIT effort to establish the Ragon Institute of Massachusetts General Hospital, MIT, and Harvard. He gave the Raman Lectures and was elected a fellow of the American Academy of Arts and Sciences. He taught two mandatory lecture courses for first-year graduate students in chemistry and chemical engineering. He was awarded Best Teacher Award by a direct vote of the chemical engineering graduate students. Professor Chakraborty serves as a steering committee member of the Ragon Institute. He is chair of the graduate recruiting committee for chemical engineering, leading another very successful recruiting effort. He also serves as an editor of *Biophysics Journal*, on numerous editorial boards, university and government advisory boards, and committees of the National Academy of Engineering and American Academy of Arts and Sciences.

Professor Clark K. Colton was honored by being named one of the 100 chemical engineers of the modern era by AIChE as part of their 100th anniversary activities.

Professor Robert E. Cohen was the 2009 Bayer Distinguished Lecturer at the University of Pittsburgh, where he described his ongoing research in "Designing Robust Omniphobic Surfaces" and "Exploitation of Layer-by-Layer Assembly in Bioinspired Materials Engineering." Students and postdocs from Cohen's research group continue to find success in academic careers, with new additions to the faculty at the University of Pennsylvania, Rose–Hulman Institute of Technology, and the University of Michigan in the past year. The year 2009 also marked the tenth consecutive year in which Cohen has administered the activities of DMA. Collaboration with professor Michael Rubner of the Department of Materials Science and Engineering has led to a vibrant, five-company research consortium that is developing a significant portfolio of intellectual property in the area of multifunctional thin-film coatings.

Professor Patrick S. Doyle continued work in the area of fundamental studies of complex fluids in microfluidic flows and fields. This past year he was invited to deliver the Van Ness Lectures at Rensselaer Polytechnic Institute, a keynote talk at the International Symposium on Applied Rheology in Seoul, and several other invited talks. Pat received the Pioneers in Miniaturization Award from Lab on a Chip Journal, Royal Society of Chemistry, Corning Inc.; a John Simon Guggenheim Fellowship; and a Rothschild-Yvette Mayent-Institute Curie Award. He spent the year on sabbatical at the Institute Curie and the École Supérieure de Physique et de Chimie Industrielles in Paris.

Professor William H. Green was appointed editor of the *International Journal of Chemical Kinetics*. He chaired the School of Engineering's faculty search in energy. Professor Green partnered with C.K. Law of Princeton University to organize the successful proposal for the new Energy Frontier Research Center in Combustion Science, which will bring about $1 million in funding to MIT. He received the American Chemical Society's Glenn Award in Fuel Chemistry at the national meeting in Salt Lake City in March 2009.

Professor Paula T. Hammond began her new role as executive officer of the department in August 2008 and has been enjoying working with the department and engaging with the undergraduate program. The Hammond group continues to explore electrostatic assembly methods for energy device applications. A 2008 *Advanced Materials* paper on the use of layer-by-layer nanoscale assembly methods for methanol fuel cell proton exchange membranes from polyelectrolyte multilayer nanoassembly was featured in *The*

Economist, *Forbes*, and *Technology Review*. Professor Hammond's research collaboration with professor Angela Belcher on patterned virus microbatteries was published in the *Proceedings of the National Academy of Sciences* and recognized this past year by *Discover Magazine* as one of the "Top 100 Science Stories of 2008"; it was also featured in the journal *Nature*. Finally, recent developments reported in the *Journal of the American Chemical Society* in 2009 on all-multiwall carbon nanotube arrays from layer-by-layer in collaborative work with the Yang Shao-Horn group has also garnered interest with regard to capacitive electrodes and storage applications. Professor Hammond also leads a collaborative effort with the Belcher group funded by Eni via MITEI; this project was initiated in 2008 as well. Continued development of targeted drug delivery systems for cancer and thin-film drug-release coatings has led to invited lectures at the Gordon Research Conference on Drug Carriers in Medicine and Biology and the 2009 American Chemical Society Workshop on Polymers for Biomedicine. Within the biomaterials area, her 2008 paper in *Angewandte Chemie* on block copolymers for gene delivery was noted as the second most cited publication of the journal year. Finally, Professor Hammond demonstrated the flexibility of new processing approaches to multilayer assembly systems that was published and featured in the June 2009 issue of *Nature Materials*. Professor Hammond also delivered the Karl Kammermeyer Distinguished Lecture at Iowa State University in 2008.

Professor T. Alan Hatton continued to serve as director of the David H. Koch School of Chemical Engineering Practice, where he has continued to maintain the international flavor of the program by placing student teams at host companies in Switzerland, Singapore, and India, in addition to the US. He is also an active participant in SMA CPE. Professor Hatton is a member of the scientific advisory board of the Particle Fluids Processing Center at the University of Melbourne. Over the past year, he has given a number of invited lectures at American Chemical Society, AIChE, and International Society for Pharmaceutical Engineering meetings as well as a keynote talk at the Conference on Revolutionary Approaches to Hazard Mitigation in Edinburgh. Seminar invitations included those by the Indian Institutes of Technology in Mumbai, Delhi, Madras, and Roorkee and the Universities of Melbourne (Australia), Karlsruhe (Germany), Crete, and Arizona State. Professor Hatton served on the organizing committee of the International Solvent Extraction Conference ISEC '08 (Tucson 2008) and on the international advisory committee for Polymer Networks (Cyprus 2008). He is on the editorial board of the journal *Current Opinion in Colloid and Interface Science* and is coeditor of the section on applications, and he is an advisory board member of the Engineering Conferences International 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 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 October 2008, Professor Jensen was inducted into the American Academy of Arts and Science, while at the centennial meeting of AIChE; he was selected as one of the 100 "Chemical Engineers of the Modern Age" for his leadership in multiscale simulations and microreaction technology. During the past academic year, he gave plenary lectures at the 2008 Micro- and Nano-Engineering Conference, Labautomation 2009, and the AIChE annual meeting. He was elected to the Governing Board of the Technical University of Denmark and continued to serve on the scientific advisory board for the Singapore A*STAR Institute for Nano and Biotechnology, the international advisory panel for Danish research infrastructure, and the steering committee for the International Conference on Miniaturized Systems for Chemistry and Life Sciences.

Professor Jesse H. Kroll joined the department in January 2009, in a joint appointment with Civil and Environmental Engineering. His research focuses on the evolution of organic species and fine particulate matter in the earth's atmosphere. His laboratory, which includes a large environmental chamber for the study of atmospheric reactions, is located in Parsons Lab (Building 48) and will be completed in July 2010.

In 2008, Institute Professor Robert S. Langer was named one of the top 100 chemical engineers of the 20th century by AIChE. He also received the Boston History and Innovation Collaborative Innovation in Health and Technology Award and the AIChE Founder's Award and was named the Isadore Rosenberg Lecturer at the Metrowest Medical Center. In 2009, he received honorary degrees from Harvard University and the Mt. Sinai School of Medicine. He was awarded the University of California, San Francisco, medal and the New England Institute of Chemists Distinguished Chemist Award. He was named the Melvin L. Samuels Lecturer at the University of Texas MD Anderson Cancer Center and the American Chemical Society Cecil Brown lecturer.

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 Dana Scholar for human immunology, an associate member of the Eli and Edythe L. Broad Institute, and associate faculty of the Ragon Institute of Massachusetts General Hospital, MIT, and Harvard. He delivered invited lectures at various locations including the National Institute of Materials Science (Tsukuba, Japan), Genentech, the MIT Club of Hartford Colloquium for Teachers, and the International AIDS Vaccine Initiative. The Love laboratory published the first example of measuring the apparent affinities of antibodies produced by single primary B cells in the *Proceedings of the National Academy of Sciences*.

Professor Kristala J. Prather continued her research in the areas of metabolic engineering and synthetic biology, with an expanded focus on biofuels. In addition to several presentations at professional conferences, she gave invited lectures at Synthetic Biology 4.0 (Hong Kong) and the Hong Kong University of Science and Technology and delivered plenary lectures at Advances in Synthetic Biology (London, UK) and the 3rd Summit on Systems Biology (Richmond, VA). Prather was featured in a *Science Careers* profile in February 2009.

Professor Gregory C. Rutledge stepped down as executive officer of the Department of Chemical Engineering in August 2008 in order to take a sabbatical leave. During this time, he held a visiting faculty position in the School of Engineering and Applied Sciences at Harvard University and served as editor and author for the upcoming *Handbook on Polymer Crystallization*. He is a member of the editorial board of *Polymer* and is a founding editor of the *Journal of Engineered Fibers and Fabrics*. He delivered invited lectures at Polymer Fibres 2008 in Manchester, England; the Fiber Society meeting in Montreal, Canada; Institute for Soldier Nanotechnologies smart textiles workshop and MIT's Industrial Liaison Program research and development workshop on multiscale materials modeling in Cambridge, MA; Nano for the 3rd Millennium Symposium in Prague, Czech Republic; the Materials Research Society Symposium on Electrofluidic Materials and Applications in San Francisco, CA; the International Nanofiber Symposium in Tokyo, Japan; and several companies and universities in the United States and abroad. He also developed a series of lectures on innovations in nanofibers for a new program at the Tokyo Institute of Technology, sponsored by the New Energy and Industrial Technology Development Organization. His research involves the molecular engineering of soft matter through the development of molecular simulations, materials characterization and electrospinning of polymer nanofibers. His work with electrospun fibers has been featured in *Tech Talk* and other venues.

Professor George Stephanopoulos was selected one of the 100 Chemical Engineers of the Modern Era by the American Institute of Chemical Engineers at its centennial celebration and 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 Lectureship at ETH in Zurich, Switzerland, as well as the 2008–2009 Dow M.M. Sharma distinguished professorship in chemical engineering at the Institute of Chemical Technology, Mumbai, India, where he taught a six-week course on process engineering. He continued his role as faculty codirector of the joint BP–MIT "Operations Academy" and presented lectures at University of Alberta (centenary lecturer in chemical engineering), BP-Pipeline and Logistics, University of Mumbai, IIT Bombay, and Dow Indian Global R&D Center; he was invited to present keynote lectures at the international conferences FOCAPD 2009 (Foundations of Computer-Aided Process Design) and PSE 2009 (Process Systems Engineering). He served as member of the external advisory board for the Department of Chemical Engineering at the University of California, Santa Barbara, and of the external review committee for the Department of Chemical Engineering at Purdue University.

Professor Gregory Stephanopoulos continued his research activity as director of the Laboratory of Bioinformatics and Metabolic Engineering with increased emphasis on biofuels research. Seminal research from previous years is finding its way into critical applications for the efficient production of biofuels from renewable resources. These advances have been licensed by two start-up companies that were founded on these technologies during the past year. Professor Stephanopoulos also continued his service on the advisory boards of four academic institutions and the managing board of the Society for Biological Engineering, which promotes the integration of biology and engineering to provide enabling technologies for industrial and medical applications.

He delivered this year's Robb Lecture at Pennsylvania State University and the distinguished lecture at Imperial College, London. 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 societies' meetings (AIChE, American Chemical Society, ASM), he also delivered plenary and invited lectures at the American Association for the Advancement of Science annual meeting (Boston), the Annual Conference of German Microbiology (Frankfurt), Academia dei Lincei (Italy), Annual FEBS Conference (Athens), Annual Metabolomics Society Meeting, 7th Metabolic Engineering Conference (Puerto Vallarta), and the 13th International Biotechnology Symposium (Dalian, China). During this year, professor Greg Stephanopoulos was honored with the Amgen Award in biochemical engineering and lifetime achievement award by the Massachusetts Legislature.

Professor Michael S. Strano has continued his research focusing on chemical engineering of low-dimensional systems. He received the 2008 Allen P. Colburn Award from the American Institute of Chemical Engineers and the 2008 Outstanding Young Investigator Award from the Materials Research Society. He also received the 2008 Office of Naval Research Young Investigator Award and a 2008 Alfred P. Sloan Foundation Research Fellowship. In this past year, he gave the Colburn Memorial Lectureship at the University of Delaware and the Ernest Thiele Lectureship at the University of Notre Dame. He was appointed to the editorial boards of the journals *Chemistry of Materials and Carbon* as well as to the advisory board for the *Journal of Physical Chemistry*. Professor Strano's work on carbon nanotube/virus assembled materials with Materials Science professor Angie Belcher was published in *Science*.

Professor Jefferson W. Tester's research program focused on clean chemical processing and renewable energy technologies with increasing emphasis on biomass conversion and unconventional fuel upgrading in hydrothermal media and advanced drilling technology using spallation and fusion methods. This past year, Professor Tester continued a heavy domestic and international travel schedule giving lectures and briefings on the potential of geothermal and biomass energy, including the Woods Lecture on Energy at Stanford, the Krumb Sustainable Engineering Symposium at Columbia, the Peck Lecture at Illinois Institute of Technology, and invited presentations in Canada (Hydro Quebec), Tasmania, Melbourne, (Geothermal Energy Conference), Brisbane (Queensland Geothermal Centre), Pisa, and London (British Parliament, The Geological Society of London and BP). Professor Tester was selected as a US representative for the intergovernmental panel on climate change's (IPCC) special report on renewable energy and climate change mitigation. He traveled to Brazil in January to participate in the first meeting of the IPCC panel. Professor Tester was invited to join the board of directors of the Midwest Research Institute, which oversees the operations of the National Renewable Energy Laboratory. He continued to serve on a number of advisory boards, including Los Alamos National Laboratory, Idaho National Laboratory, Energy and Environmental Science Journal, Ze-Gen, AltaRock Energy, and KUTh Geothermal. Professor Tester's teaching responsibilities included the core graduate thermodynamics class Course 10.40 Chemical Engineering Thermodynamics, and the Institute-wide core Course 10.391J Sustainable Energy. Professor Tester was selected to be the first Croll professor of sustainable energy systems at Cornell University and began serving in that position in January 2009.

Professor Bernhardt L. Trout continues in his roles as director of the Novartis–MIT Center for Continuous Manufacturing and cochair of the SMA CPE program. He also runs a laboratory of 20 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. He was a member of the Committee on the Undergraduate Program as well as multiple other Institute and departmental committees. He gave more than 10 invited talks.

Institute Professor Daniel I.C. Wang was the opening lecturer at the "First Sustainable Green Technology Conference," National Taiwan University, Taipei, Taiwan, in July 2008. He was also invited to be a member of the external scientific review board, Biomedical Research Council, A*STAR, Singapore, in September 2008 to review the past research activities of A*STAR's Research Institute. In November 2008, Professor Wang was invited to "National Cheng Kung University Forum," Tainan, Taiwan, to deliver three lectures. In October 2008, he delivered an opening lecture at the "13th International Biotechnology Symposium," Dalian, China. He delivered the keynote lecture at the "International Conference on Recent Advances in Biotherapeutics," Mumbai, India, February 2009. Finally, he was chairman of the scientific advisory board for the Bioprocessing Technology Institute, Singapore, March 2009.

Research Highlights

Microbial Synthesis of Value-Added Biochemicals (Kristala Jones Prather)

Increasingly, biology is being looked to for sustainable alternatives to petroleum. Much of the focus has been toward a replacement for liquid transportation fuels; however, there is a related need for a variety of chemicals from renewable sources. The carbon derived from biological species such as plant matter can be converted to molecules that may substitute for fossil fuels or petrochemicals, and this conversion process may be mediated by biological systems. In particular, microbes are well-known for their ability to transform carbohydrates into a variety of chemical structures, from simple compounds such as ethanol to complex natural products such as the chemotherapeutic agent taxol.

The field that first encompassed targeted genetic engineering to optimize microbial production systems is known as metabolic engineering. Going beyond improvement of natural producers, metabolic engineering increasingly features the transference (functional assembly) of metabolic pathways from an intractable source organism to a more easily manipulated host, followed by systemwide analysis and optimization using the many analytical and experimental tools of the trade. To this end, metabolic engineering overlaps with the evolving practices of synthetic biology, characterized by the desire to design—or redesign—living biological systems, construct them through a well-defined assembly process, and observe predetermined outputs based on the quality of the design. The primary interest of the Prather Lab is in the design process as it applies to de novo biosynthetic pathways. They seek to design and assemble novel metabolic routes toward biochemicals either as alternatives to naturally occurring but unwieldy routes or to facilitate biological synthesis of molecules without known biological origin. This process is achieved by treating individual enzymes as interchangeable parts that can be obtained from any biological source. Throughout the assembly process, they develop and use tools and techniques to address the challenges inherent in colocating enzymes from diverse sources in a single heterologous host.

The group has recently applied these principles toward the design of novel pathways for the production of organic acids. In particular, the compounds of interest have been identified as "top value-added" biochemicals for production in a biorefinery in a 2004 report from the Department of Energy (Werpy and Peterson; Figure 2). In one example, they have converted a biomass-derived substrate, levulinic acid, to high-value 3- and 4-hydroxyvalerates, molecules that are useful as chiral building blocks and as monomers in the production of biodegradable plastics. The process uses an engineered strain of *Pseudomonas putida* that carries a recombinant gene from *Escherichia coli* and can give titers approaching 20 g/L at a small scale. 4-Hydroxyvalerate can be enzymatically converted to valerolactone, a molecule that has been proposed as a renewable fuel additive. However, this reaction requires acidic pH, a condition not achievable inside the bacterial cell. Instead, they have developed a process in which the enzyme is exposed to the extracellular medium, which can be acidified. Adjustment of the pH following production of high-titer hydroxyvalerate improves lactone yield tenfold.

A second Department of Energy compound of interest is glucaric acid. It is found in fruits, vegetables, and mammals and has been studied for therapeutic purposes including cholesterol reduction and cancer chemotherapy. It also has potential use as a building block for a number of polymers, including new nylons and hyperbranched polyesters. Although glucaric acid has a natural biosynthetic route, the pathway is

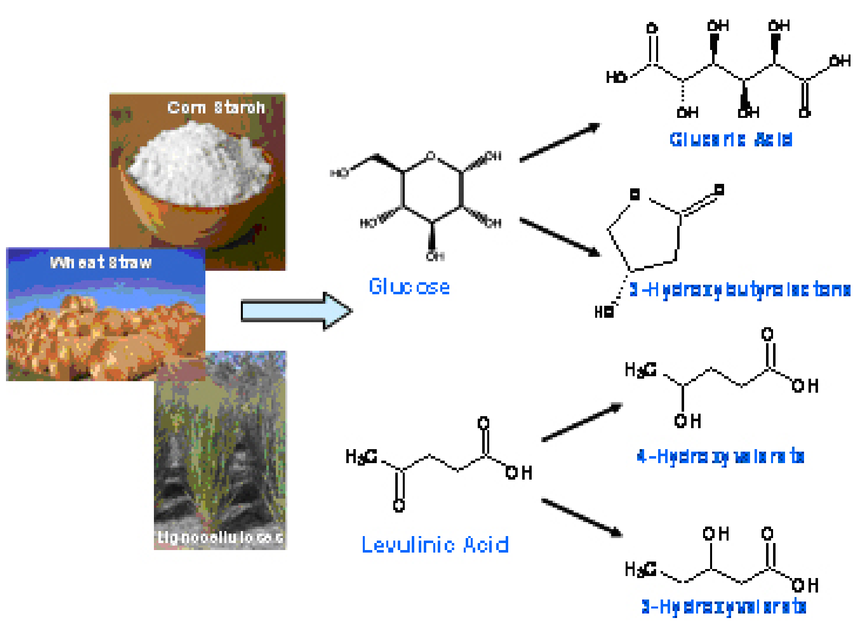

Figure 2. Various biomass-derived feedstocks can be converted to simple sugars such as glucose, or to more complex compounds such as levulinic acid. Custom designed and constructed microbes can take these substrates and convert them to value-added compounds including hydroxyvalerates, glucaric acid, and 3-hydroxybutyrolactone.

complex and not readily amenable to reconstitution in a microbial host. Instead, they created a synthetic pathway originating from glucose and utilizing three enzymes, one each from yeast (*Saccharomyces cerevisiaie*), mammalian (mouse), and bacterial (*Pseudomonas syringae*) origins. This pathway utilizing naturally occurring enzymes assembled in an unnatural way resulted in glucaric acid production at the gram-per-liter scale. Maximum productivity could be improved more than twofold by using synthetic protein scaffolds to colocalize the enzymes with various stoichiometries to overcome inherent limitations in the activity of the mouse enzyme (in collaboration with Dr. John Dueber of the Synthetic Biology Engineering Research Center).

The final department compound of interest is 3-hydroxybutyrolactone (3-HBL), a compound with widespread use as a chiral building block for pharmaceuticals. Unlike the previous two examples, 3-HBL production has not been previously identified in any biological system. The immediate precursor to this molecule, 3,4-dihydroxybutyric acid (DHBA), is structurally similar to one of the hydroxyacids, 3-hydroxyvalerate, described earlier. By mimicking a natural route for the production of this compound, they successfully produced DHBA from glucose and the inexpensive compound glycolate. Concomitant with its production was a smaller amount of the desired substance 3-HBL. To their knowledge, this is the first demonstrated production of this value-added compound through biological conversion of biomass-derived substrates.

As industry and consumers continue to look for "green" and renewable alternatives to many commercial products, the ability to engineer biology should be increasingly useful for the development of microbial chemical factories. Approaches for the de novo design of biosynthetic pathways should facilitate this increased use of microbial synthesis of chemicals. Additionally, their development of generally useful devices should be applicable to engineer many systems and improve productivity.

Predictive Tools for Protein Aggregation and Binding (Bernhardt L. Trout)

Protein aggregation has many undesirable effects, both for therapeutic proteins used in disease treatment and for proteins involved in biological processes. Aggregation causes therapeutic proteins to lose their activity and raises concerns about potential immunogenicity. Similarly, protein aggregation in vivo is associated with a number of neurodegenerative disorders such as Alzheimer's and Creutzfeldt–Jakob diseases and type II diabetes. Therefore, there is a tremendous need to understand the regions that are prone to protein aggregation and to devise methods to prevent aggregation. Whereas protein aggregation is undesirable, protein binding is essential for many biological functions such as cell signaling, metabolism, gene expression, and immune responses. Identifying these binding regions helps in understanding the protein function and in designing drugs to effectively target those binding regions involved in diseases such as cancer. Therefore, identifying protein aggregating and binding regions is of utmost importance to gain a fundamental understanding of biological processes and to develop effective drugs. To this end, professor Bernhardt Trout of MIT, together with Dr. Bernhard Helk of Novartis and postdoctoral assistants Naresh Chennamsetty, Veysel Kayser, and Vladimir Voynov, are developing molecular computational and experimental techniques to accurately predict the protein aggregating and binding regions.

A molecular computational technology called spatial aggregation propensity (SAP) was developed that can predict both protein aggregating and binding regions with good accuracy (*Proceedings of the National Academy of Sciences* 2009). SAP indicates the dynamically exposed hydrophobic regions that are prone to aggregation or binding. It was applied to two model therapeutic antibodies, antibody A and antibody B, to predict their aggregating regions. Mutations engineered at sites responsible for the peaks of SAP led to antibodies of enhanced stability. The sites chosen for mutation are shown in Figure 3. The mutants were then tested for their aggregation behavior by using accelerated aggregation experiments under heat stress. Size-exclusion high-performance liquid chromatography (SEC-HPLC) was used to determine monomer loss over time after heat stress. The SEC-HPLC results for antibody A indicated a monomer increase from 91% for wild type to 92% to 97% for the variants, indicating enhanced stability of the mutants. Similarly for antibody B, the SEC-HPLC results showed monomer increases from 95% for wild type to 96% to 100% for the variants, except for two mutations (B_1 and B_5). Apart from this exception, the variants in general were more stable than the wild type, providing validation that high values of SAP correspond to regions prone to aggregation. Thus, the SAP technology can be used along with genetic engineering techniques to design therapeutic proteins with enhanced stability.

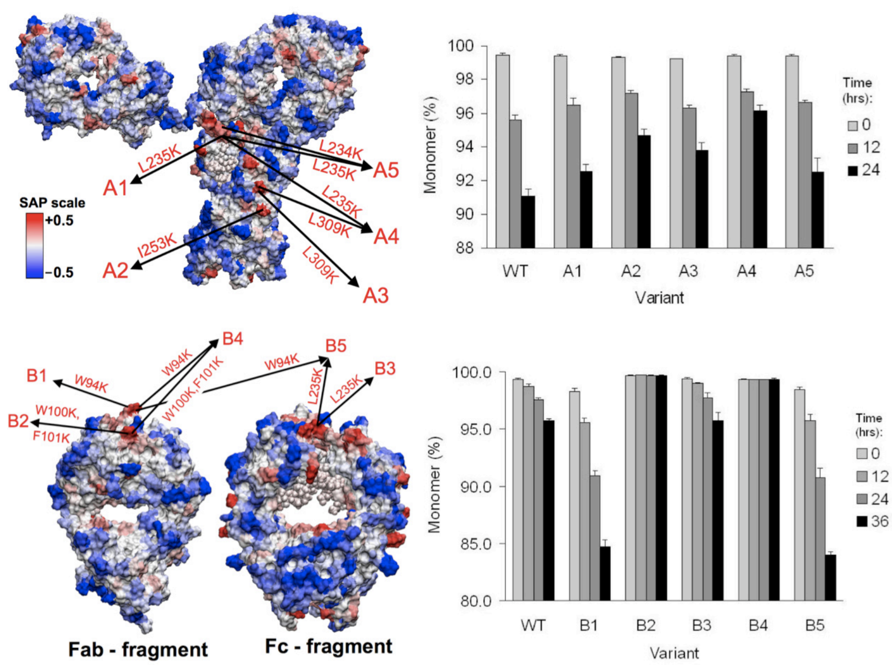

Figure 3. Spatial-aggregation-propensity (SAP) mapped onto antibody-A and antibody-B along with the peaks, A1 to A5 and B1 to B5, chosen for mutations. Also shown is the monomer loss from accelerated aggregation experiments that indicate the stability of wild type and variants.

The SAP technology was also demonstrated to predict protein binding regions with good accuracy. The SAP tool was applied to two model proteins, an IgG1 antibody and epidermal growth factor receptor (EGFR), to predict their binding regions. For EGFR, the binding regions with EGF, transforming growth factor, and with another EGFR correlate well with SAP peaks (Figure 4). For the antibody, the binding regions with Fc receptor, protein A, and protein G correlate very well with SAP peaks. Some of these peaks also coincide with confirmed aggregating regions shown in Figure 4. Thus, the SAP tool shows that some of the protein binding regions overlap with the aggregating regions. This finding presents a challenge for therapeutic protein design because unfavorable aggregation needs to be prevented while preserving the protein binding necessary for its function. This challenge can be addressed by using SAP analysis followed by protein engineering. With SAP, the sites near the binding site that are involved in aggregation can be found and modified to decrease aggregation propensity while preserving binding. This process was demonstrated using the IgG1 antibody where the aggregation-prone regions near the protein A binding sites were modified to decrease aggregation while preserving the binding capacity (*Proceedings of the National Academy of Sciences* 2009). Similar protein engineering based on SAP could be performed near the antigen binding regions to decrease aggregation propensity while preserving activity. Thus, the SAP tool described here could be used to design stable therapeutic proteins while preserving their binding capacity.

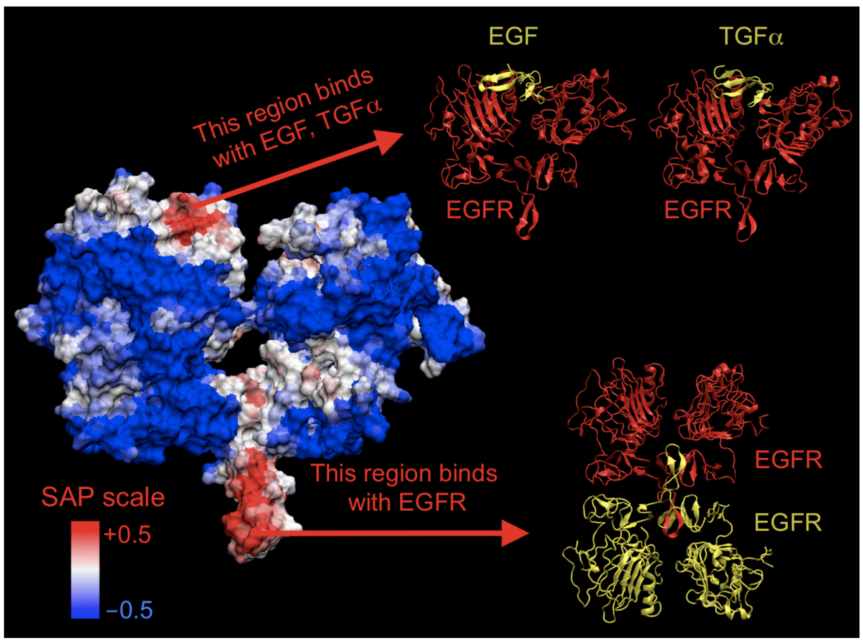

Figure 4. Spatial-Aggregation-Propensity (SAP) mapped onto the EGFR structure. The high SAP regions that bind with EGF, TGF and another EGFR are also marked.

In summary, several molecular computational and experimental techniques were developed to predict protein aggregating and binding regions. The SAP technology based on molecular computations was used along with genetic engineering techniques to predict and validate the aggregating regions of therapeutic antibodies. Apart from antibodies, the SAP tool was used to identify aggregation-prone regions on other proteins and peptides as well. With the mounting number of protein therapeutics, this technology could greatly improve the developability screening of candidate biopharmaceuticals or further stabilize the selected candidates. SAP technology could also be used to predict protein binding regions, especially for the proteins of interest as disease targets. Furthermore, it can determine the unknown binding sites for numerous proteins coming from structural genomics initiatives, thereby providing important clues to their function.

Annual Lectures, Seminars, and Symposia

The 2008–2009 academic year saw several interesting and successful events, including its series of four annual major lectures. Webcasts for all chemical engineering major lectures can be accessed at http://web.mit.edu/cheme/news/webcast.html.

In the fall, Vinod Khosla, founder of Khosla Ventures, delivered the 23rd Hoyt C. Hottel Lecture in Chemical Engineering, cosponsored by MITEI. Mr. Khosla's lecture, "Extrapolate the Past … or Invent the Future," involved a rousing discussion of the present and future of research possibilities.

Our first speaker for the spring semester was professor Peter Schultz, Scripps professor of chemistry at Scripps Research Institute and director of the Genomics Institute of the Novartis Research Foundation. He visited March 20 as our delayed Frontiers of Biotechnology lecturer. Professor Schultz's lecture, "Synthesis at the Interface of Chemistry and Biology," filled the Kirsch Auditorium (Building 32-123) to capacity with standing room only.

April brought another standing-room-only event: the 15th Alan S. Michael Lecture in Medical and Biological Engineering, "Recognition and Delivery: The Next Generation of Medical Microdevices," by alumnus Nicholas A. Peppas, Fletcher S. Pratt chair of chemical engineering, biomedical engineering, and pharmaceutics at the University of Texas at Austin.

The final lecture of the semester was the 31st annual Warren K. Lewis Lecture by William F. Banholzer, executive vice president and chief technology officer of Dow Chemical Company. Mr. Banholzer's timely presentation, "The Impact of Mega Economic Trends on the Chemical Industry and Chemical Engineering Profession" was of great interest to our students as they determine their career paths.

Our departmental seminar series also featured a distinguished group of academic and industry leaders from LS9, Inc.; Weizmann Institute of Science; University of Wisconsin–Madison; Stanford University; University of California, Berkeley; Cambridge University; California Institute of Technology; and Imperial College of London. As part of the spring seminar series, the department also presented some of its own faculty to prospective students as they visited campus: professors Kristala Jones Prather and Michael S. Strano.

Departmental Awards

The department awards ceremony took place on May 11, 2009, in the Gilliland Auditorium of the Ralph Landau Building. We are pleased to recognize this year's recipients of the Outstanding Faculty Awards: professor Arup K. Chakraborty was the graduate students' choice and professor Herbert H. Sawin was selected by the undergraduate students.

The Edward W. Merrill Outstanding Teaching Assistant Award was presented to graduate student Jamila Saifee for her work in 10.37 Chemical Kinetics and Reactor Design. The Outstanding Graduate Teaching Assistant Award was presented to Vicki Dydek for her service to 10.50 Analysis: Transport Phenomena.

Chemical engineering special service awards were conferred to members of the graduate student council: Adekunle Adeyemo, Joshua Allen, Emily Chang, Himanshu Dhamankar, Jyoti Goda, Patrick Heider, Jaisree Iyer, Becky Ladewski, Bradley Niesner, Michael Petr, Justin Quon, and Yuxi Zhang. In addition, Ming Yang was awarded the Chemical Engineering Rock for outstanding athleticism and Kathryn Schumacher 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 Wayne Blaylock and Joseph Scott.

Our undergraduates also earned numerous accolades over the course of the year. Johnathan Cromwell received the William L. Stewart Jr. Award for his outstanding contributions to extracurricular activities and events during the year. The Genentech Scholar Award recognizes outstanding students in disciplines related to production and development and was presented to Timothy Humpton. The Merck Fellowship Award was presented to Michael Blaisse in recognition of his scholastic excellence. Shenwen Huang was presented with the Cunningham Scholar Award, which is given to promote women in engineering. Senior Alona Birjiniuk received the Henry Ford Scholar Award for maintaining a cumulative average of 5.0. The Robert T. Haslam Cup, which recognizes outstanding professional promise in chemical engineering, went to Jacqueline Douglass. 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 Jason Whittaker.

The department is quite pleased to recognize Rosangela Dos Santos as the department's outstanding employee of the year for her dedication and exceptional service to faculty, staff, and students. The School of Engineering Infinite Mile Award went to department members Sara Darcy, financial coordinator for the administrative services organization, and Suzanne Easterly, academic administrator. Employees Beth Tuths and Steve Wetzel were presented with this year's Chemical Engineering Individual Accomplishment Awards. Also for 2009, George Stephanopoulos, Barbara Balkwill, and Glori Collver-Jacobson 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 in 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.