MASSACHUSETTS
INSTITUTE
OF TECHNOLOGY

Chemical Engineering Alumni News

Spring 2007
Course X

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FROM THE HEAD OF THE DEPARTMENT...

Professor Klavs Jensen
Head, MIT
Chemical Engineering

As the Spring 2007 edition of the department's newsletter is about to go to press, Bob Armstrong is stepping down as department head. As of February 1, I take on the challenging task of following Bob. With the transition, we include letters from both the incoming and outgoing department head.

The department is deeply grateful to Bob for a decade plus of exceptional leadership and service. For the seventeenth consecutive year, both our graduate and undergraduate programs were ranked number one among chemical engineering departments in the 2006 *U.S. News & World Report* academic survey. Moreover our outstanding faculty received numerous prestigious awards and generated nearly $30 million in research volume - an indication of the exciting, vibrant research in the department. The incoming graduate class also promises to continue our tradition of research and academic excellence. These accomplishments and others described in this newsletter give evidence to Bob's superb leadership of chemical engineering at MIT.

The department has prospered with Bob at the helm. We have engaged in two major strategic planning exercises, which have impacted the discipline of chemical engineering broadly. The image we first articulated of chemical engineering - as the central engineering discipline - has been adopted around the world. We have launched significant, groundbreaking new degree programs: the PhDCEP and X-B at the graduate and undergraduate levels, respectively. With Alan Hatton's efforts, our Practice School has truly spread around the world, and we have remained number one in the rankings of chemical engineering graduate and undergraduate programs. Bob has led a nationwide effort to rethink undergraduate education in chemical engineering and his efforts were acknowledged by the 2006 Warren K. Lewis award from the AIChE (page 8). This prestigious award recognizes distinguished and continuing excellence in chemical engineering education. The impact of Bob's own research efforts were also acknowledged in 2006 by the Bingham Medal from the Society of Rheology – the top recognition in the field of rheology (page 8).

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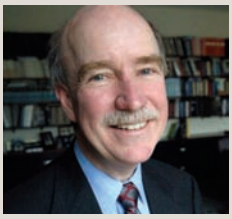

Professor Robert C. Armstrong
Former Head, MIT
Chemical Engineering

Welcome to the Spring 2007 edition of the department's newsletter. It is good to have the opportunity to bring you up-to-date on the department. The past two years have been particularly introspective as we have looked hard at the changes in the world that impact chemical engineering and have been actively translating our vision of the future into new educational and research programs. It has been and continues to be an exciting journey, which I will say more about later.

As is evident already from the cover of this Newsletter, a significant, personal item that I want to share with you is that after nearly eleven years I have decided to step down as head of the department. I have enjoyed the past eleven years immensely, but I think that the department will benefit from a fresh set of eyes, ears, and ideas that a new head would bring to the job. I am also anxious to refocus on research and education.

Dean Magnanti appointed Professor ***Klavs Jensen*** to be the new Department Head, effective February 1, 2007. I cannot say enough about how fortunate we are to have Klavs agree to do this. To a person, the faculty is enthusiastic about this choice and fully behind Klavs. As many of you already know, Klavs is a noted chemical engineering researcher and educator. He has made seminal contributions to a wide variety of arenas including microfabrication, testing and integration of microfluidics in the context of chemical and biological discovery, synthesis and processing. In this arena he is well known, for example, for his pioneering research on "chemical processes on a chip." He has also investigated and taught broadly in areas such as materials synthesis and processing, multiscale simulation of reactive processes, chemical kinetics, and transport processes. Many of you will remember him from 10.65.

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Editor's Note:
Welcome to the Spring 2007 Alumni Newsletter; the content of this edition spans the academic year 2005-2006. The next edition, covering 2006-2007, will be published this coming Fall 2007. Enjoy!

ALSO IN THIS ISSUE:

Practice School News

By Professor T. Alan Hatton

The ***David H. Koch School of Chemical Engineering Practice*** continues to be a dynamic and unique educational opportunity within the department, attracting top students from around the country and the world. During the summer of 2005, we had 17 students attend stations in Minneapolis, Boston, and Basel, Switzerland. For the 2005-2006 academic year, 17 students worked on projects in Minneapolis, the UK and Ireland, and Suffern, NY. We welcomed a new host company to the program, GlaxoSmithKline in the UK, whose projects provided outstanding practical opportunities for our students. Thank you to all our host companies who have helped provide the kind of education that only these hands-on, real-world challenges can offer.

During the summer of 2005, the Practice School conducted two simultaneous student groups. One group traveled to Cargill in Minneapolis, where they worked under the direction of ***Robert Fisher***; they then moved on to Billerica, MA, (outside Boston) where they worked at Cabot under ***Bill Dalzell***. The second group of students began at Cabot, then flew to the Novartis Pharmaceuticals station in Basel, Switzerland, directed by ***Barry Johnston***.

The first session's projects at Cargill included a design/feasibility study for the utilization of an alternative fuel, proof-of-concept experiments for a continuous crystallization-separation process for a potential new product, and development of a dynamic model used to evaluate process alternatives and energy integration schemes at an existing bio-refinery. The second session involved three projects: catalyst deactivation, reactor design and performance evaluations. Applications ranged from new product development to commercial implementation. Through the success of our work and the diligent efforts of our students, Cargill has expressed the idea of collaborative extensions of some of our practice school projects.

In June of 2005, nine MIT students at Cabot worked on laboratory and pilot plant projects involving the measurement of the particle size of pigments, modification of the surface chemistries of carbon black and metal oxides, and development of a new laboratory quality assurance test for carbon blacks. The three August projects consisted of adsorption of polymers on carbon black, a continuation of the quality assurance study started in June, and novel methods of preventing ingress of liquid chemicals into the pores of particles. The environment at Cabot was highly technical, dynamic, and enthusiastic.

Most projects for the nine Practice School students at Novartis's development organization in Switzerland focused on resource use. This included quantifying capacity of a multipurpose batch facility, defining needs for new development and chemical synthesis facilities, and developing a model to organize workflow in a particular division. Other projects involved technical problems in solid-phase delivery applications. Between their projects in synthesis and sold-phase delivery, the students were able to find time to visit the Swiss countryside and hike up a few alpine "hills".

In the fall and spring semesters of '05-'06, we operated a station at General Mills (GMI), under the direction of ***Robert Fisher***. To date, GMI has hosted 68 projects at various locations. These collaborations with MIT have been quite successful with many leading to commercialization. This year's station was based at its James Ford Bell Technology Center just outside Minneapolis.

The fall program at GMI was divided in to two sessions. During the first fall session, our students were involved with the cereal division's activities: modeling transport phenomena, conceptual design/feasibility studies, and development of operational maps for alternative processing concepts. The second fall session involved two projects that extended work from session one, while the other two second session projects concerned metrics in the Pillsbury dough making process and a new snack design. During the spring program, the students worked with teams from Progresso soup, YoPlait, Pop-Secret, and Pillsbury. Here, the full range of chemical engineering fundamentals was utilized: heat, mass, and momentum transport, thermodynamics, the molecular and material sciences, chemical reaction engineering, and advanced mathematics. Our students' experience at GMI was quite well-rounded!

The other fall station was at new host GlaxoSmithKline (GSK) in Harlow, UK, and Cork, Ireland, directed by ***Bill Dalzell***. We were very excited for the chance to work with this major global producer of pharmaceuticals. In Harlow, the students worked on modeling the strength of multiplayer tablets, developing an improved model for dissolution of drugs in the gastrointestinal tract, and developing a model for the physical structure of a spray-dried product. During the second month, the project moved to Cork, where they studied the formation of microcapsules and the capacity of spray dryers, as well as developing a model for filter dryers.

The Novartis manufacturing facility in Suffern, NY, was the home for the second spring '06 Practice School Station. Eight students attended the station, directed by ***Stephen Martin***, and worked with members of the Global Process Analytical Technology group and local manufacturing teams. The students' first project was a collaboration with a student from Purdue, and involved the control of particle sizes produced during roller compaction. The second concerned the analysis of manufacturing lines at the Suffern facility. Novartis's second session consisted of three projects: a continuation of the roller compaction project, data mining and analysis of process data, and a project based on MIT recommendations during the process optimization project. Two students used a software package to develop a detailed process model of one of the manufacturing lines at the plant. Their efforts were extremely well-received by their sponsors and others within the organization.

Also, a congratulations to Novartis Suffern Station Director ***Stephen Martin***, who has moved on to be an assistant professor of chemical engineering at Virginia Tech. Stephen was a great asset as a station director. We will miss him, but wish him the best on this next step in his career. Stephen's research interests include soft materials, interfaces and self-assembly.

The 2005-2006 academic year continued our tradition of innovative approaches to chemical engineering education. We could not do this without the partnership and enthusiasm of our host organizations. Not only do they help to reinforce chemical engineering applications, but they exemplify the passionate and collegial culture of our discipline. We look forward to future industrial collaborations!

Novartis Station, Suffern, NY, Spring 2006: from L to R: Fei Chen, Aruna Mohan, Arman Haidari, Steve Martin (Station Director), Jonathan Mendenhall, Saurabh Tejwani, Curtiss Schneider, Jie Chen, Terence Tai-Weng Sio

Professor Klavs Jensen from page 1

In her May 2005 inaugural address MIT President Susan Hockfield called for a renewed Institute commitment to energy-related research and education. Bob Armstrong and Professor Ernest J. Moniz (Physics and Engineering Systems Division) co-chaired the Energy Council with faculty representatives from all five schools. Being department head is already a time intensive multifaceted job, but handling both department and a major Institute initiative is a true Herculean labor. In May 2006, the council produced a detailed report (http://web.mit.edu/erc/) of MIT's future role in addressing the world's energy challenges. The recommendations are being implemented by the newly established MIT Energy Initiative (MITEI) in which Bob will play a leading role as its Associate Director. Clearly energy is an issue of great importance and opportunity for chemical engineering; the department looks forward to working with MITEI to continue our long tradition of innovation and contribution to energy research. Although Bob will be busy in the Initiative's headquarters (E40) and fundraising, we hope he'll also find time to use his chemical engineering office and share his many experiences from 10+ years of leadership.

THANK YOU Bob - you have been a great department head. Best wishes for your new initiatives over the coming months and years!

As I take over as department head, I plan to meet with the various constituents to learn more about the needs of the department and help formulate a joint vision for the future. With senior faculty moving on to becoming university presidents (Bob Brown at Boston University and Alice Gast at Lehigh University, see pages 12 and 8) and retirements, we are in position to hire new outstanding faculty – a process which is well underway with Dane Wittrup chairing the search committee. Paula Hammond's graduate admissions committee will again be working hard this spring with faculty to attract the very best graduate students. The quality of our faculty and students are critical to maintaining the stature of the department; I thank everyone involved for their considerable efforts to identify and attract top notch talent. I also look forward to working with the faculty to translate Bob's curriculum activities into the classroom and to help faculty develop broad research initiatives furthering the department's worldwide leadership in chemical engineering.

You, our alumni, play an important role in this process by your continued engagement with and support of the department. I encourage you to provide feedback on how we are doing and how we can improve. Thank you for your support and best wishes for the coming year.

2005 Chemical Engineering Fellowships

Edwin R Gilliland '33 Fellow
Erin Rebecca Bell
University of Wisconsin Madison 2005

John Henry Grover (1948) Fellow
Omar Berrios
University of Puerto Rico Mayaguez 2003

Haas Family Fellow/NSF Fellow
Jennifer Elizabeth Seto
Rutgers University 2005

Robert T Haslam (1911) Fellows
Russell Evan Cooper
University of California Berkeley 2005
Daniel Warner Trahan
Rice University 2005

Frederic A L Holloway '39 Fellow
Amy Sue Chan
Case Western Reserve University 2004

George M Keller (1948) Chevron Fellow
Dominick John Blasioli IV
Tufts University 2005

George M Keller (1948) Fellows
Kevin Daniel Fowler
University of Minnesota Minneapolis 2005
Baris Erinc Polat
Carnegie Mellon University 2005

Tae-Sup Lee Graduate Fellow
Seung Woo Lee
Seoul National University 2004

Jerry (1940) & Geraldine Mcafee Fellow
Khek-Khiang Chia
University of Michigan Ann Arbor 2005
Hang Zhou
Tsinghua University 2005

R C Reid (1954) & G Williams Fellow
Tai-Weng Sio
MIT 2005

Robert J Richardson (1954) Fellows
Benjamin Aaron Fine
University of Western Ontario 2005
Christopher Henry Marton
University of Waterloo 2005

Charles And Hilda Roddey Fellow
Jeffrey Robert Millman
North Carolina State 2005

William & Margaret Rousseau Fellow
Brian Michael Simpson
Johns Hopkins University 2005

Keith And Helen Rumbel Fellow
Jing Tang
Tsinghua University 2005

Adel F. Sarofim (1962) Fellow
Laura B. Shimmin
MIT 2005

Arch Chilton Scurlock (1943) Fellow
Ian Matthew Slattery
University of Rochester 2005

John C Sluder (1941) Fellow
Tae Seok Moon
Seoul National University 1998

H. (1953) & L. Stern Practice School Fellow
Jonathan Patrick McMullen
Lehigh University 2004

Frank Hall Thorp Fellow
Stanislas Bailly
Ecole Polytechnique 2004

David S. Wong Fellow
Bo Gong
Tsinghua University 2005

Alkermes Fellow
David V. Liu
Stanford University 2005

Lemelson Minority Engineering Fellows
Michael Richard Harper Jr.
University of California Berkeley 2005
Neidi Negron Rodriguez
University of Puerto Rico Mayaguez 2004

Shell Companies Graduate Support
Chia-ling Pai
National Taiwan University 2005

ChE Practice School Fellows
V.N. Ravikanth Annavarapu
Indian Institute of Technology Madras 2005
Anusha Kothandaraman
University of Bombay 2005

MITSCEP 1936 Course Xa Fellow
Christopher Calbone Govern
University of Virginia 2005

DuPont-MIT Alliance Fellows
Zekeriyya Gemici
Cornell University 2005
Clarke Alan Low
Brigham Young University 2005

Robert T Haslam (1911) Presidential Fellow/NSF Fellow
Ethel Mae Victoria Loewer
California Institute of Techology 2005

Robert T Haslam (1911)Presidential Fellows
Daniel J. Schmidt
University of Michigan Ann Arbor 2005
Huan H. Zheng
Princeton University 2005

Walsh (1937) Memorial Presidential Fellow/NSF Fellows
Donnie Wayne Blaylock
Tennessee Tech University 2003
Kelly Jennifer Davis
Johns Hopkins University 2004

Walsh (1937) Memorial Presidential Fellows
Amanda Catherine Engler
University of Wisconsin Madison 2005
Daniel Klein
University of Texas Austin 2005
Tsz Leung To
University of Massachusetts Amherst 2005

Practice School Awards for Outstanding Performance

Rosemary J. Wojtowicz Award
Ernest Saudjana

J. Edward Vivian Award
Rocco Ciccolini

Jefferson W. Tester Prize
Sernyik Chee

William C. Rousseau Award for Leadership and Ethics
Robert Ashcraft

Awards Day

By Mary Wesolowski, Graduate Student Coordinator

The annual Awards Ceremony for the Department of Chemical Engineering was held on Monday, May 15, 2006, in the Gilliland Auditorium. Professor and Department Head, ***Robert C. Armstrong***, presided over the event.

Professor Armstrong began the ceremony by recognizing Chemical Engineering members that have been awarded scholarships outside the department:

With collaboration form the Student Financial Aid Office, the Department awarded **Merck Fellowships** to seniors ***Ben Wasserman*** from Boca Raton, FL and ***Chris Tostado*** from Monrovia, CA.

The **National Barry M. Goldwater Scholarship** is given out annually to one Chemical Engineering undergraduate in the Department. This year, ***Alexander Bagley*** from Needham, MA, and a junior at MIT, was the winner of this prestigious award. Alexander lists his career goals as an MD or PhD in biomedical/tissue engineering, moving on to conduct research and teach at the university level.

In addition, several staff members were honored with the School of Engineering Infinite Mile Award. The Infinite Mile Award Program of the Offices of the Provost and the Vice President for Research and Associate Provost is designed to recognize those individuals or teams who have made extraordinary contributions within their own organizations to help the Institute carry out its mission. ***Amanda Tat*** and ***Aza Gevorkian*** from the Administrative Services Office and ***Gwen Wilcox***, an administrative assistant for Professors Prather and Tester, received **Infinite Mile Awards** this year from the School of Engineering.

The **Robert T. Haslam Cup** was awarded to ***George Eng.*** George is a senior from Boston, MA, and was recognized with this award for outstanding professional promise in Chemical Engineering.

The **Roger de Friez Hunneman Prize** is the oldest in the department and is given to an undergraduate for outstanding scholarship and research. This year the award went to senior ***Joshua Michener*** from Chapel Hill, NC.

The **Edward W. Merrill Outstanding Teaching Assistant (TA) Award** was presented to two outstanding TAs this year: ***Joseph Lowery*** and ***Sanjoy Sircar***. Joseph Lowery is a graduate student from Findlay, OH, honored for his work with 10.10 in the fall. Sanjoy Sircar is a graduate student from Allentown, PA, and considered outstanding for his work with 10.302, also in the fall.

The **Outstanding Graduate Teaching Assistant Award** recognizes excellence in teaching in graduate subjects. This year the award went to ***Kristin Mattern*** from Schnecksville, PA, for her work with the fall 10.50 class.

Professor Bob Armstrong presents the Special Services Award to deserving students.

(From l to r) Bill Green, Jean-François Hamel and Kristala Prather receive the C. Michael Mohr Outstanding Teaching Award.

Every Monday two graduate students present to their peers the progress of their research and are evaluated on their presentations. Three graduate students were recognized for giving outstanding seminars. This year **Outstanding Seminar Awards** went to ***Ginger Chao*** from Ann Arbor, MI, for her seminar during the fall term; ***Daniel Pregibon*** from Findlay, OH, and ***Kris Wood*** from Georgetown, KY, were recognized for their spring seminars.

The **Chemical Engineering Special Service Awards** were given to members of the Graduate Student Committee for their outstanding work during the year. 2005-2006 GSC members were ***David Adrian*** from Warren, MN, ***Nathan Ashcraft*** from Springfield, MO, ***Nathan Aumock*** from Fridley, MN, ***Kevin Brower*** from South Windsor, CT, ***Franklin Goldsmith*** from Raleigh, NC, ***David McClain*** from Turnersville, NJ, ***Dan Perez*** from Elizabeth, NJ, ***Mridula Pore*** from Derby, UK, and ***Ben Wang*** from San Jose, CA. The current AIChE president ***Andrea Dooley*** from Saint Cloud, MN, also received a **Special Service Award**.

The **Chemical Engineering "Rock" Award** for outstanding athletics, as voted by the graduate students of the department, went to ***Nathan Aumock***, from Fridley, MN, for his active participation in a variety of Intramural sports.

Administrative assistant ***Gwen Wilcox*** won the **Outstanding Employee Award** for her support of Professors Kristala Prather and Jeff Tester and her exceptional dedication and contributions to the department.

Each year the graduate students vote for the recipient of the **Outstanding Graduate Faculty Award**. This year it went to Professor ***William Deen***, and was presented by Ben Wang. The Outstanding Undergraduate Teaching Award, renamed the **C. Michael Mohr Outstanding Teaching Award**, was presented to Professor ***Kristala J. Prather***, Professor ***William Green*** and Lecturer ***Jean-François Hamel***. This award was renamed to recognize and remember Senior Lecturer C. Michael Mohr's immense contributions as undergraduate officer and AIChE advisor to our chemical engineering students.

Faculty Appointments & Promotions

In the Department of Chemical Engineering

New Faculty Appointment

Assistant Professor Maheshri Welcomed to Faculty

The Chemical Engineering Department is pleased to welcome newly appointed Assistant Professor ***Narendra Maheshri***, who joined the department in the spring of 2006. Professor Maheshri received his BS in chemical engineering and biology at MIT in 1999 with a very impressive record, and was awarded an NSF Graduate Fellowship prior to arriving at the University of California, Berkeley, for his graduate work in chemical engineering. Before joining the MIT faculty, Professor Maheshri did post-doctoral research with Professor Erin O'Shea at the University of California, San Francisco. Professor Maheshri's focus area is cell signaling, and his planned research here is the design of evolvable biological systems.

"My undergrad years at MIT were a good experience; the fond memories made it easy to come back," he explains. He also cites MIT's "student quality" as the number one reason he returned to teach. Professor Maheshri's addition to the faculty bolsters our already accomplished group of teaching and research staff.

Welcome to Professor Chakraborty from Berkeley

Before arriving at MIT in the fall of 2005, Professor ***Arup Chakraborty*** was the Warren and Katharine Schlinger Distinguished Professor and Chair of the Department of Chemical Engineering at the University of California, Berkeley. He is one of the leading chemical engineering theorists worldwide and has made seminal contributions to numerous areas during his career to date. These include heterogeneous catalysis, polymer self-assembly, polymer interfaces, sensor technology for pathogen detection, and cell-cell recognition for the immune system. In this latter area, he has developed the first quantitative model of how the immunological synapse forms, which is critical in detecting pathogens. He showed that this synapse functions as an adaptive controller that can both respond to rare ligands and also stop signaling above a threshold so as to prevent antigen-induced cell death.

Professor Chakraborty has been recognized with numerous awards and honors, including a Camille and Henry Dreyfus Teacher Scholar Award, AIChE's Allan P. Colburn Award and Professional Progress Award, as well as recent election to the National Academy of Engineering.

After only a year here, Professor Chakraborty has proven himself as a respected teacher and mentor to his graduate students… as well as an excellent squash player.

Faculty Promotions

Barton Promoted to Full Professor

Paul I. Barton is an expert in process system engineering – the analysis, synthesis, design, and optimization of chemical and biological manufacturing processes as entire systems. The themes of modeling, simulation, and optimization of large-scale dynamic systems unify his broad research program. He has made contributions to hybrid discrete/continuous dynamic systems and applied these fundamental advances to a range of important problems in the chemical process industry, including the design of batch processing systems, the design of process safety systems, the modeling and design of complex distillation systems, and the design of operating procedures.

Professor Barton has played a central role in the teaching of process design and the use of computers in the chemical engineering curriculum at MIT. In undergraduate education, he has introduced the use of process flowsheeting and dynamic simulation by students to solve realistic process design problems. In graduate education, he has worked in the development of a new core graduate level class that addresses the treatment of process systems engineering.

Hammond Promoted to Full Professor

Paula Hammond received her SB in chemical engineering from MIT in 1984 and her Ph.D. in chemical engineering also from MIT in 1993. Her focus is the synthesis of tailored, functional materials. She works primarily through the molecular design and synthesis of self-assembling polymeric systems. She has demonstrated that polyelectrolyte multilayers can be compositionally tuned on

the nanometer length scale for the development of low cost, low weight, thin film electrochemical devices. She has also developed polyelectrolyte multilayer systems for biomedical and biomaterials applications, and demonstrated the practical application of linear-dendritic diblock copolymer constructs as delivery vehicles for biomedical applications.

Professor Hammond has made significant contributions to both graduate and undergraduate education in the department and more broadly at MIT. At the graduate level, she co-developed a new subject entitled "Molecular Aspects of Chemical Engineering," which focuses on the molecular underpinnings of structure/property relationships. In our undergraduate program, she has brought new synthesis and characterization experiments to our large polymer laboratory subject. She is also active in the interdepartmental Program in Polymer Science and Technology.

Trout Receives Tenure

Bernhardt L. Trout is a leader in the broad area of molecular engineering, and impacts the design of products and processes by developing quantitative, molecular understanding of these systems. His research addresses issues that range from developing fundamental understanding of clathrate-hydrates, which are a potentially important source of clean fuel and a means for carbon dioxide sequestration, to developing new automotive catalysts for reducing emissions in high sulfur fuels, as well as finding new approaches to minimize degradation of therapeutic proteins (drugs).

Professor Trout is the co-chair, together with Professor Raj Rajagopalan of Singapore, of the Singapore - MIT Alliance's Chemical and Pharmaceutical Engineering Program. This is an educational/research program involving 20 students per year and over 16 faculty members from MIT and schools in Singapore. The program focuses on developing new technologies for both biological and chemical pharmaceuticals.

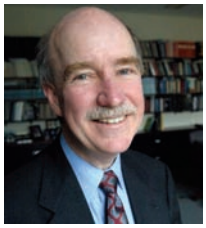
Professor Trout engages the full range of our students, from leading freshman advising seminars to teaching advanced graduate electives. He has also led curriculum reform of our undergraduate program, and also designed and implemented an innovative freshman Undergraduate Research Opportunities Program (UROP) experience.

Doyle Promoted to Associate Professor

Patrick Doyle specializes in transport phenomena, particularly the fluid mechanics and rheology of polymeric liquids and the microstructural description of these fluids. Since joining the department, Doyle has developed a research program in polymer and colloidal particle dynamics and has made ground breaking contributions to these fields. He effectively combines concepts from polymer physics, fluid mechanics, and rheology to study problems in lab-on-a-chip separations, molecular mechanics, and rheology. His work is characterized by uses of single molecule observations; dynamics simulations; and novel experimental techniques, including microfluidics, to solve fundamental problems with practical applications. For example, he has demonstrated the use of post micro-arrays to greatly reduce the time required to fractionate DNA relative to traditional electrophoretic methods.

Professor Doyle has played a key role in bringing molecular concepts and understanding into the core education program in chemical engineering. He has taught regularly in the graduate core in chemical engineering and in biological engineering. In addition to developing a new undergraduate subject in molecular engineering, he has taught a hands-on microfluidics IAP subject for freshmen and sophomores since coming to MIT.

Faculty Awards Highlights



Armstrong Receives Bingham Medal and Lewis Award

We're proud to announce that Professor ***Robert C. Armstrong*** is the 2006 recipient of the Bingham Medal by the Society of Rheology, which is devoted to the study of the science of deformation and flow of matter. This honor has been awarded annually since 1948 to an individual who has made an outstanding contribution to the science of rheology or has performed particularly meritorious service to the Society. The Bingham Medal is considered the top prize for accomplishments in rheology research. Professor Armstrong received the prize and delivered a lecture and at the society's 78th Annual Meeting in October 2006, in Portland, Maine.

Also, at the AIChE's Annual Meeting in November 2006, Professor Armstrong received the Warren K. Lewis Award for Chemical Engineering Education. The Lewis Award recognizes distinguished and continued excellence in chemical engineering education. Recipients are honored for having made lasting impact through successes in and out of the classroom. These include contributions of lasting influence through superior textbooks and lectures, demonstration of creative ability (evidenced by contributions to literature, inventions, industry and service), and leadership in administration.

For more about the Bingham Medal, please visit **www.rheology.org/sor/awards/bingham/default.htm**

For more about the Warren K. Lewis Award, please visit **www.aiche.org/About/Awards/WarrenKLewisAward.aspx**

Cohen Honored as AIChE Fellow, Receives School of Engineering Mentoring Award

Professor ***Robert E. Cohen*** has been named a fellow of AIChE for his significant accomplishments in chemical engineering and his contributions to the profession. This honor is extended to less than 2 percent of the professional association's 50,000 members.

Professor Cohen has also been selected as the first recipient of the Capers (1976) and Marion McDonald Award for Excellence in Mentoring and Advising. Established by Capers and Marion McDonald, this award is presented to a faculty member in the School of Engineering, who, through tireless efforts to engage minds, elevate spirits, and stimulate high quality work, has advanced the professional and personal development of students and colleagues.

Evans Elected President of AIChE

Professor Emeritus ***Lawrence Evans*** (MIT Professor from 1962-1990) has been elected the next president of AIChE. During his tenure at MIT, Dr. Evans was instrumental in the introduction of computer aids for chemical engineering education. For his campaign for the AIChE presidency, he again turned to a new technology: the Internet. Dr. Evans created a website, **www.larryevans.net**, specifically to share his ideas and positions on issues and to communicate directly with AIChE members.

Dr. Evans served as chairman of Aspen Technology until his retirement in 2005. Since then, he has been very active in the local Boston chapter of AIChE. His vision and dedication to AIChE are apparent and we look forward to his continued service to the chemical engineering profession!

Alice Gast Wins ACS Award, moves on to Lehigh

Professor ***Alice Gast***, chemical engineering professor and vice president for research and associate provost, was selected as the winner of the ACS Award in Colloid and Surface Chemistry, presented at the American Chemical Society meeting in March 2006 in Atlanta. This annual award, established in 1952, is presented to an individual who demonstrates outstanding scientific contributions to colloid and/or surface chemistry, with consideration for originality and independence of thought, and the technological impact of the nominee's contribution.

Also this year, Professor Gast became President Gast: she was appointed president of Lehigh University in Bethlehem, PA. She assumed leadership there on August 1, 2006. The department will miss her, but we are proud to see her move on to be the first female president of Lehigh!

For more about the ACS Award in Colloid and Surface Chemistry, please visit **www.chemistry.org/portal/a/c/s/1/acsdisplay.html?DOC=awards\colloid.html**

Jensen Earns Danish Honorary Degree

Congratulations to Professor ***Klavs Jensen***, who was recognized with an honorary degree in April 2006 at the Technical University of Denmark or "doctor technices honoris causa," the highest honor that DTU can confer. DTU honored Professor Jensen for his "ground-breaking and truly fundamental contributions to the development of chemical engineering, in particular within chemical reaction engineering, micro-electronics and micro-reactors – and all with a great impact on the chemical industry."

Professor Jensen earned his MS from DTU in 1976 before moving on to his PhD work at the University of Wisconsin in 1980.

Langer Earns Top Honors

Institute Professor ***Robert Langer*** has been awarded the 2005 Materials Research Society (MRS) Von Hippel Award. Professor Langer was cited for "pioneering accomplishments in the science and application of biomaterials in drug delivery and tissue engineering, particularly in inventing the use of materials for protein and DNA delivery." The award was presented to Professor Langer at the 2005 MRS Fall Meeting on November 30, 2005 in Boston.

Professor Langer was also honored in 2005 with the $500,000 Albany Medical Center Prize in Medicine and Biomedical Research, America's top prize in medicine, second only to the Nobel Prize in Physiology and Medicine.

"The world owes an infinite debt of gratitude to Dr. Langer for his pioneering work in the field of drug delivery systems that has improved the lives of more than 60 million people each year," said James J. Barba, chairman of the board, president and chief executive officer of Albany Medical Center.

For more about the MRS Von Hippel Award, please visit **www.mrs.org/s_mrs/sec.asp?CID=1796&DID=68716**

For more about the Albany Medical Center Prize, please visit **www.amc.edu/Academic/AlbanyPrize/index.html**

Prather Designated ONR Young Investigator

Professor ***Kristala Jones Prather*** was one of only two MIT professors selected as 2005 Office of Naval Research (ONR) Young Investigators. This program is designed to attract young scientists and engineers who show exceptional promise for outstanding research and teaching careers. In a letter to MIT President Susan Hockfield, U.S. Navy Rear Admiral Jay Cohen writes, "We believe that ONR Young Investigators are among the best and brightest young academic researchers this country has to offer."

For more on the ONR Young Investigators Program, please visit **www.onr.navy.mil/sci_tech/3t/corporate/yip.asp**

Rutledge Elected APS Fellow

Professor and Department Executive Officer ***Greg Rutledge*** was elected as a fellow of the American Physical Society (APS) at its November 2005 meeting. This honor was in recognition of his outstanding contributions to physics, specifically "for the development and application of theoretical, modeling, and experimental methods to develop quantitative relationships between the chemical architecture and the materials properties of macromolecules."

The APS Fellowship Program was created to recognize members who have made advances in knowledge through original research and publication or made significant and innovative contributions in the application of physics to science and technology. Election to Fellowship in the American Physical Society is limited to no more than one half of one percent of the membership.

For more on the APS Fellowship Program, please visit **www.aps.org/fellowship/2005/index.cfm**.

Faculty Distinctions

In the Department of Chemical Engineering

Professor **Robert Armstrong** continued to serve as Department Head. During 2005, he served as Chair of the Council for Chemical Research and is very active in leading a series of discipline-wide discussions on "Frontiers in Chemical Engineering Education." This educational activity has as its goal the first major revision in chemical engineering undergraduate curriculum in over 45 years. He was named the 2006 winner of the Bingham Medal of the Society of Rheology, the Society's highest honor. During this past academic year he gave invited/plenary lectures at the Ninth International Conference on Chemical Engineering in Portugal, at Texas Tech University, Purdue University, and Wayne State University. He serves on the advisory boards of chemical engineering departments at Georgia Tech, Northwestern University, Virginia Tech, the University of Washington, the University of Wisconsin, and Stanford University. He co-chaired MIT's Energy Research Council with Professor Ernest Moniz from Physics.

Professor **Daniel Blankschtein** continued to serve as Graduate Officer during the fall of 2005, being responsible for the educational and social well-being of approximately 220 graduate students in the Department. His research group conducts fundamental theoretical and experimental research in the area of Colloid and Interface Science, with emphasis on industrially and biomedically relevant applications. Professor Blankschtein's teaching responsibility included the interdisciplinary course 10.55 – *Colloid and Surfactant Science*, which was well attended by students from across the Institute. Professor Blankschtein and his students delivered oral presentations and presented posters at the American Institute of Chemical Engineers (AIChE) Annual Meeting, at the Meeting of the Society of Cosmetic Chemists (SCC), at the Meeting of the American Academy of Dermatology, at the International Conference on "Biopartitioning and Purification" held in the Netherlands, and at the Conference on "Enzymatic Hydrolysis and Biomass" held in Brazil. Professor Blankschtein delivered an invited talk at the 2005 Gordon Research Conference on "Barrier Function of Mammalian Skin," and continues to serve in the Editorial Board of Marcel Dekker's Surfactant Science Series.

Professor **Robert E. Cohen** at MIT, he continues to direct the operation of the DuPont MIT Alliance, a broadly based $5 million/year research and education collaboration, now in its seventh year of operation. He also served the Institute for a second year as Chair of the Committee on Nominations, which is charged with the responsibility of staffing the various standing committees of the faculty. His numerous invited and contributed research presentations included a plenary presentation at the Asilomar Conference on Polymers in Pacific Grove, CA. His collaborative research with Professor Michael Rubner of the Materials Department at MIT led to patent applications on novel antifogging coatings, a topic that received widespread attention in the popular press, and garnered radio and TV coverage. He successfully competed in 2005 for a post in the MIT-Balliol College Exchange Program, and in January of 2006 he took up his position of Visiting Fellow at Balliol. The visiting position also affords access to Oxford University's Department of Engineering Science, the site of Professor Cohen's year of postdoctoral study in 1973.

Professor **Charles L. Cooney** continued as the Faculty Director of the Deshpande Center for Technological Innovation and chaired the Center's annual IdeaStream Symposium in April 2006. He took a leadership role in defining the manufacturing initiative in the Center for Biomedical Innovation (CBI) and continued as the co-lead, representing the School of Engineering, in developing the MIT BP Projects academy in partnership with the Sloan School of Management. Professor Cooney chaired a symposium on Academic Innovation at the Chemical Heritage Foundation in March. He continued as Chair of the FDA Advisory Committee for Pharmaceutical Sciences and is a member of the MIT Community Service Fund Board, the Lemelson MIT Screening Committee and the MIT Committee on Intellectual Property. Professor Cooney is also an Overseer of the Boston Symphony Orchestra and a Trustee of Boston Ballet.

Professor **Patrick S. Doyle** was invited to give the Colburn Memorial Lecture at the University of Delaware. He co-developed and ran a short course on microscopy as applied to rheology at the annual Society of Rheology meeting in Vancouver. He delivered invited talks at several conferences and institutions including the American Chemical Society (ACS) Special Symposium on Confined Fluids, ACS Special Symposium in Honor of Alice Gast, Stanford University, New England Complex Fluids Meeting and US Genomics. His work entails fundamental studies of complex fluids in flows and fields.

Professor **Karen K. Gleason** returned from a sabbatical year at GVD Corporation, a start-up company she co-founded, to become Associate Director of MIT's Institute for Soldier Nanotechnology. Professor Gleason was awarded the Professor Franciscus Cornelis Donders Chair which supported her as a visiting professor in the Department of Physics and Astronomy at University of Utrecht, Netherlands, in the summer of 2006. In the past year, she presented a keynote address to the MIRAI Low-k Workshop in Tsukuba, Japan, and also gave invited presentations on her group's research on chemical vapor deposition technology at IMEC (Leuven, Belgium), the Chemical Engineering Department at the City College of New York, the Electrochemical Society Meeting (Denver), and the American Institute of Chemical Engineers (Cincinnati).

Professor **William H. Green** received the Certificate of Merit from the American Chemical Society's Division of Environmental Chemistry, for research on solvation. He taught in the Summer School on Sustainability in 2005, in the faculty short course in Energy in 2006, and served on the Energy Research Council. He was elected to the board of the regional section of the Combustion Institute.

Professor **Paula T. Hammond** continues her service as the Chair of Graduate Admissions for the Department. New developments in the formation of sequential drug delivery thin films led to a second year of funding from the Deshpande Center for Innovation and a landmark paper on the method in the Proceedings of the National Academy of Science. Other new research thrusts include a collaborative effort with Professor Angela Belcher of Materials Science and Biological Engineering in the incorporation and self-assembly of viruses in polyelectrolyte multilayer systems, which led to papers in Nature Materials and Science (with Professor Yet-Ming Chiang) in 2006. Exploratory research efforts continued in the development of linear-dendritic block copolymers for drug delivery and nanostructured materials, with new sponsorship provided by the NIH. Professor Hammond delivered lectures at numerous universities, corporations and conferences, including the Japan-American Conference on Hybrid Materials and Nanostructures in Asilomar, CA, the Gordon Conference on Biopolymers at Salve Regina University in Newport, RI, and the Gordon Conference on Supramolecular Chemistry in Ventura, CA. She also participated in a symposium series on Commercializing Academic Innovation at the Chemical Heritage Foundation and was the keynote speaker for the Robert M. Langer Symposium held at Yale University. She continues to serve as a Team Leader and active researcher in the Institute for Soldier Nanotechnologies

Professor **Kristala Jones Prather** joined the faculty in 2004 and is establishing a laboratory with research focused on design of biosynthetic pathways for microbial production of organic chemicals. Her work builds upon advances in metabolic engineering and the nascent field of synthetic biology. She was recognized with a Camille and Henry Dreyfus Foundation New Faculty Award in 2004. This year, Professor Prather received an award for outstanding undergraduate teaching.

Professor **Gregory C. Rutledge** continued his role as the Executive Officer of the Department of Chemical Engineering. He is a member of the editorial board of *Polymer* and is a founding editor of the *Journal of Engineered Fabrics and Fibers*. He serves on the Gender Equity Committee for MIT's School of Engineering, the Research Award Selection Committee of the Society of Plastics Engineers and co-organized the American Chemical Society (ACS) Symposium on Advances in Methods and Applications of Molecular Simulation. He delivered invited lectures at the University of Nebraska, the 5th International Discussion Meeting on Relaxations in Complex Systems, the ACS Symposium on Complex Fluids in Confined Spaces, Autopolymer '05, Techtextil, and the 34th annual Leermakers Symposium at Wesleyen University on "Challenges to Chemistry from Other Disciplines." His research involves the molecular engineering of soft matter through the development of molecular simulations, materials characterization, and electrospinning of polymer nanofibers.

Professor **Jefferson W. Tester's** research program focuses on clean chemical processing and renewable energy technologies with new research thrusts in biomass conversion in hydrothermal media and advanced drilling technology using spallation and fusion methods. This past year, he continued to serve as chair of the National Advisory Council of the U.S. Department of Energy's National Renewable Energy Laboratory and as co-chair of the Governor's Advisory Committee of the Massachusetts Renewable Energy Trust. He also served on advisory boards for Los Alamos National Laboratory, Cornell University, American Council on Renewable Energy, and the Paul Scherrer Institute of the Swiss Federal Institute of Technology (ETH). He gave invited lectures at the University of Colorado, Imperial College, University of Alberta, Stanford University, Italian Energy Festival, Osaka Prefecture University, The Royal Society, Rensselaer Polytechnic Institute, ENEL Rome's Energy Challenges Conference, and Barcelona's Energy Technology Conference. During the summer of 2005, Professors Tester and Jeffrey Steinfeld (MIT-Chemistry) led an American Chemical Society (ACS) PRF sustainability short course at MIT. A new textbook - *Sustainable Energy - Choosing among Options* – co-authored by Professor Tester along with Professors Michael Golay and Michael Driscoll (MIT- Nuclear Engineering) and Drs. Elizabeth Drake (LFEE) and William Peters (ISN) was released by MIT Press. In the spring of 2006, Professor Tester spent time at Chalmers Technical University in Sweden as the Wenner-Gren Distinguished Lecturer.

Professor **Bernhardt L. Trout** set up major new projects with biopharmaceutical companies. The objectives for these are to understand degradation mechanisms of therapeutic proteins and antibodies and use that understanding to engineer new generation biopharmaceutical formulations. He has also set up new projects in the areas of energy and the environment. He has been invited as a Plenary Lecturer in the Physics and Chemistry of Ice Conference in Bremerhaven, in addition to the Protein Stabilization Conference in Breckenridge. He has given several invited talks at universities, including Texas A&M, Drexel, The University of Rome (Italy), and the Institute for Advanced Studies in Trieste (Italy). He also continues to be a Fellow of Next House.

MIT Provost and Chemical Engineering Professor Bob Brown to Lead Boston University

We are happy to announce that on Saturday, June 4, 2005, MIT Provost and Warren K. Lewis Professor of Chemical Engineering ***Robert A. Brown*** was chosen as Boston University's (BU) tenth president. President Brown took the helm at BU on September. 1, 2005.

Below are excepts from the June 8, 2005 MIT Tech Talk article: Dr. Brown first joined the department in 1979 as an assistant professor and rose through the ranks to department head, dean of engineering in 1996 and provost in 1998. Although his geographic move was now taking him just across the Charles River, he said it would not be easy to leave the Institute.

"I am incredibly excited about the wonderful opportunity to lead Boston University, but this excitement is not without some sadness brought on by the terribly difficult act of actually leaving MIT," said Dr. Brown. "MIT is a special place because of the quality of its faculty, students and staff, who are all dedicated to a common mission of excellence in everything they do. It has been an indescribable honor to serve this community as provost, dean and department head."

Professor ***Robert C. Armstrong*** recalls a bit about the process of hiring the Dr. Brown as an assistant professor in 1979.

"He interviewed in March as I recall, right after a spring snowstorm," said Professor Armstrong. "Back then the nearest hotel was the Hyatt, so we put him up there for his visit. To get to the department he had to walk down the sidewalk along Memorial Drive. Of course, with the big snowbanks and melting, the sidewalk was more like a water trough than a sidewalk. Bob said he thought this was a test to see if he could walk on water in order to get a job at MIT. The rest is history."

In a letter to chemical engineering faculty and staff, Professor Armstrong said Dr. Brown "has had a profound impact on almost every aspect of the department and Institute. He set exceptionally high standards for teaching and research, as is evident from the numerous teaching awards he won, as well as from the external awards for research that he won: the Colburn Award, the Professional Progress Award and election to both the National Academy of Engineering and the National Academy of Sciences, to name a few. As executive officer and then department head, Bob played a leading role in bringing many of our current faculty to MIT and in ratcheting up the already high standards of the department.

"I suspect that we have all been struck with his seemingly boundless energy and enthusiasm for all that he does and for his endless ability to absorb and digest data. His ability to synthesize creative solutions to difficult problems was refreshing," said Professor Armstrong.

"Bob is a gifted leader," said Professor ***Alice Gast***, vice president for research and associate provost at MIT. "I feel that he has an exceptional ability to understand and be sympathetic to all sides of an issue. He is great at consensus-building and bringing diverse teams together to solve problems. He holds himself and his colleagues to the highest standards of scholarship and integrity.

"His legacy includes greatly enhancing the research environment at MIT, including the building of the Stata Center and the launch of the Broad Institute and the Computational and Systems Biology Initiative," Dr. Gast said. "He has done much for the infrastructure and environment that cause research and education to thrive at MIT.

"He is also a great family man and very mindful of the need to balance work and family life. He has shared many personal stories of great outdoor adventures in New England that were wonderful for me as my family and I settled in New England," she added.

The department held a symposium on December 9, 2005, to honor Dr. Brown's work in chemical engineering. For more information, go to page 19.

Armstrong Tapped to Co-Chair Energy Research Council

Professor Robert C. Armstrong (center) and the Energy Research Council meet with U.S. Secretary of Energy Samuel Bodman on May 9, 2006.)

MIT President ***Susan Hockfield*** announced a new energy initiative in her inaugural address May 6, 2005, saying that MIT has a responsibility to address the world's energy problems. "Over the last thirty years, these two words — energy and the environment — have gotten a little tired, tired not from over-use but from lack of progress. I believe that the time for that progress is now. I believe that the country and the world may finally be ready to focus on these matters seriously," she said.

Our own Professor ***Robert C. Armstrong*** was chosen to co-chair the Energy Research Council (ERC) with former undersecretary for the U.S. Department of Energy and MIT Physics Professor Ernest J. Moniz. The ERC consists of 16 members from each of MIT's five schools: science, engineering, management, architecture and planning, and humanities, arts and social sciences. Our Professor ***Bill Green*** is also a member of the Council.

"All the schools will be engaged, because the involvement of economists, architects, urban planners, political scientists, and management experts is crucial to make sure that the research results can be rapidly deployed in the real world," Professor Armstrong said.

As reported by MIT Tech Talk on May 3, 2006, the ERC released its 50-plus page Report to the President, thrusting MIT into a new era of energy research, education, and campus initiatives. The report calls for an energy-focused laboratory or center with its own research space to be established within five years, and an independent steering organization to carry out MIT's new energy initiatives.

"The need for new global supplies of affordable, sustainable energy is perhaps the single greatest challenge of the 21st century," the report states. "Increasing tension between supply and demand is exacerbated by rapidly escalating energy use in developing countries, security issues facing current energy systems, and global climate change. These converging factors create an unprecedented scenario requiring a multifaceted approach to increasingly urgent energy issues."

In conjunction with the release of the report, the Institute sponsored a daylong "MIT Energy Forum: Taking on the Challenge" in Kresge Auditorium. The forum featured talks by 19 MIT faculty members whose work represents some of MIT's many areas of energy-related research in science, technology and policy. Speakers from our own Chemical Engineering faculty included Professor ***Armstrong***, Professor ***Gregory Stephanopoulos*** (who spoke on biofuels as a technology for a clean energy future), Professor ***Bill Green*** (who chaired a session on improving today's energy systems), and Professor ***Jeff Tester*** (who discussed the ERC's Education Subcommittee).

For more about the Energy Research Council, please visit **http://web.mit.edu/erc/**

For more about the May 3rd Energy Forum and the ERC Report to the President, please visit **http://web.mit.edu/erc/forum/**

Chemical Engineering PhDCEP student gives stock tips to Warren Buffett

PhDCEP student Patrick de Man (left) with Warren Buffett (center) and Michael Fox of Sloan (right).

On Monday, April 10, 2006, a group of MIT Sloan Students visited Berkshire Hathaway in Omaha, NE, to meet with Warren Buffett, the world-renowned investor who is also the company's chairman. Weeks before the meeting, the MIT students held a competition to identify a stock or company to pitch Mr. Buffett as a learning exercise; the winning students would then make the pitch themselves at the April 10th meeting.

ChemE's ***Patrick de Man*** **(PhD '06)** won the competition in a tie with ***Michael Fox***, a fellow MBA student at Sloan, and thus were chosen to represent MIT in a joint presentation to Mr. Buffett.

De Man and Fox recount the experience:
"The day began with a 2-hour Q/A session that ranged from the current U.S. economic situation, to Mr. Buffett's modest lifestyle (his favorite luxury is Internet bridge), to his source for true happiness: his family and friends. Importantly, we learned Mr. Buffett's simple, but exceptionally effective, investment

philosophy. For example, he explained how by breezing through readily available one-page summaries of Korean companies, he was able to choose some very successful investments.

Next, we had the challenge of pitching an investment idea to the World's Greatest Investor. We had spent more than a week before this visit preparing our presentation with the help of 11 other MBA students and Jeffrey Shames, Sloan's executive-in-residence. As a student in the PhDCEP program in Chemical Engineering, Patrick was well suited to the technical aspects of the company's products and was able to identify the company's source of competitive advantage. Michael, a Sloan MBA student with prior experience in the finance industry, was well equipped to analyze the financial case and identify the investment themes. We worked very collaboratively, in true MIT fashion.

Mr. Buffet, aged 75 and still as sharp as ever, listened intently to our pitch and was soon probing the investment risks. While we were ready to answer a few hundred questions, it only took a couple of minutes for Mr. Buffett to conclude that we were presenting a great business – although expensive by his standards. He did mention that if the price weakens, he would be supportive of sending us on a trip to Ireland (the pitched company's base) to get to know the company better!

Our MIT colleagues agreed that this was a very unique experience; we are very grateful to Mr. Buffett for the invitation."

Langer to Co-Lead Cancer Center

(As reported in the October 5, 2005 MIT Tech Talk)
On October 3, 2005, the National Cancer Institute announced it had chosen MIT and Harvard University to share one of seven national, multi-institutional hubs it has established to rapidly advance the application of nanotechnologies to cancer research. The MIT-Harvard Center of Cancer Nanotechnology Excellence is funded with a five-year, $20 million grant organized and administered by MIT's Center for Cancer Research (CCR). Principal Investigators are MIT Institute Professor ***Robert Langer*** and Professor Ralph Weissleder, M.D., of Harvard Medical School and Massachusetts General Hospital.

Professor Langer noted, "This is a great opportunity for MIT to pursue interdisciplinary science at the intersection of cancer research and nanotechnology, and hopefully to do some real good for patients."

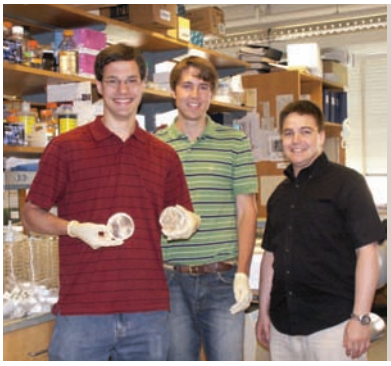
The MIT-Harvard CCNE brings together a team of more than a dozen experts across a variety of disciplines – chemistry, engineering, biology and medicine. At MIT they include Professor Langer, Institute Professor ***Phillip Sharp*** (biology), and Professors ***Tyler Jacks*** (biology, head of the CCR), ***Michael Cima*** (materials science), ***Angela Belcher*** (bioengineering), ***David Housman*** (biology), ***Moungi Bawendi*** (chemistry) and ***Sangeeta Bhatia*** (Harvard-MIT Division of Health Sciences and Technology).

The investigators will pursue five innovative cancer research projects spanning the entire spectrum of nanotechnology applications, from fabricating nanoparticles for targeted delivery of therapeutic drugs and imaging agents to implanting tiny sensors for early detection and cancer monitoring. In addition, other MIT researchers will be involved in smaller pilot projects.

One of the large projects, led by Professor Langer and his former postdoctoral fellow ***Omid Farokhzad***, now a Harvard Medical School professor, focuses on using nanoparticles to transport time-release anti-cancer drugs directly to prostate cancer cells. "One of the problems with cancer therapy is that it goes everywhere in the body," often causing toxic side effects, Professor Langer said. "We proposed making nanoparticles with units attached to them – homing devices, if you will – that would target only cancer cells."

The first challenge of this project is to isolate these "homing devices," RNA molecules called aptamers, that bind specifically to prostate-tumor antigens and will be taken up by the cancer cells. The second challenge is to construct a safe, biodegradable nanoparticle that can carry a drug on the inside and bind with an aptamer on the outside. How this and other projects will turn out is anyone's guess. But, as Professor Jacks concludes, "The best way MIT can deploy its assets in the war against cancer is to bring together people like Bob Langer and Phil Sharp on the same problem."

ChemE Students Win 2006 MIT $100K Entrepreneurship Competition



Stericoat team members (left to right) Christopher Loose, Joel Moxley and Michael Hencke. (Not pictured: Vipin Gupta and David Lucchino)

Congratulations to ChemE graduate students ***Vipin Gupta***, ***Christopher Loose***, ***Joel Moxley***, ChemE undergraduate ***Michael Hencke*** (as well as Sloan Fellow David Lucchino) on their success in winning the 2006 MIT $100K Competition!

Their coating technology, SteriCoat, won in the competition's original Business Venture category. SteriCoat targets the billion-dollar medical catheter market with an application designed to prevent the formation of bacterial "biofilms" on medical devices.

SteriCoat Techical Summary
Each year, bloodstream infections associated with medical devices cost hospitals $9 billion and cause 70,000 deaths in the US. SteriCoat is commercializing a patented antimicrobial coating to prevent these infections. SteriCoat's exclusive application technology allows us to coat devices of virtually any size, shape, or material. Furthermore, our unique mechanism of action makes the coating more durable and does not affect the performance of the coated device. Our initial market will be central venous catheters, which access the patient's bloodstream directly. Our innovation addresses two critical concerns: For patients, it increases safety by reducing the risk of infections, which prolong hospital stays and are potentially fatal. For providers, it minimizes expenses from treating bloodstream infections, which cost $10K-50K per patient.

Tester introduces Sustainable Energy Textbook

Professor Jeff Tester reads an excerpt from his new textbook to one of his most trusted colleagues, Rocky Jones.

Professor ***Jeff Tester's*** **(PhD '71)**new textbook *Sustainable Energy – Choosing Among Options* was published by MIT Press in Spring 2005.

This textbook addresses one of the foremost challenges facing the world — how to provide humankind with energy-derived advantages without damaging the environment, affecting societal stability, or threatening the well being of future generations. The book discusses current energy resources and technologies as well as some emerging technologies. Extending beyond technology, *Sustainable Energy* explores ways that energy decisions affect quality of life, commerce, mobility, and social institutions.

Developed as a textbook for senior level and graduate students, *Sustainable Energy* introduces readers to the issues and opportunities for achieving a sustainable energy future; the main goal was to develop students' skills to analyze multi-dimensional characteristics and understand the tradeoffs and uncertainties associated with pursuing alternative energy options on local and global scales. In addition to students and faculty, energy experts and non-specialists in government, industry, foundations, non-profit organizations, and the public can consider this text a valuable resource. Anyone seeking a better understanding of energy in a framework of enduring social and environmental stewardship would find *Sustainable Energy* of interest.

To learn more about *Sustainable Energy – Choosing Among Options*, visit the ChemE course website at **http://ocw.mit.edu/OCWWeb/Chemical-Engineering/10-391JSustainable-EnergySpring2003/CourseHome/index.htm** or to order the book visit MIT Press' website **http://mitpress.mit.edu** and search for ISBN 0-262-20153-4 or contact Professor Jeff Tester directly at testerel@mit.edu.

Professor Brenner Retires after 50 Distinguished Years

Professor Howard Brenner (left) receives an honorary degree from Clarkson University May 9, 2004.

After over half a century of significant contributions to chemical engineering education, Professor ***Howard Brenner*** has decided to retire.

Professor Brenner's extraordinary and accomplished career includes broad and fundamental research on low Reynolds number fluid-particle hydrodynamics, microfluidics, complex fluids, interfacial transport processes and emulsion rheology, multiphase flow and transport processes in porous media, generalized Taylor dispersion phenomena and macro transport processes, just to name a few. Professor Brenner is also co-author of *Low Reynolds Hydrodynamics*, a classic textbook and one of the most widely cited books in fluid mechanics worldwide.

Professor Brenner has had a profound impact on the profession. He has been recognized by numerous honors and awards, including election to the National Academy of Sciences and the National Academy of Engineering. He received the Fluid

Dynamics Prize from the American Physical Society and is only the second person in the history of AIChE to have received the three major Institute awards – the Alpha Chi Sigma Award in 1976 for "outstanding accomplishments in fundamental chemical engineering research", the William H. Walker Award in 1985 for "outstanding contributions to the chemical engineering literature" and the Warren K. Lewis Award in 1999 for "distinguished and continuing contributions to chemical engineering education." Each of these awards represents a singular category of accomplishment.

In 2004, Professor Brenner was awarded an honorary degree from Clarkson University, for "his outstanding intellectual achievements during a distinguished half-century career as a chemical engineering academic, and for his boldness in questioning the most basic assumptions of continuum fluid mechanics." During the ceremony, he explained how he started his career as a theoretician (as quoted by the Clarkson University News):

"I am a theoretician in the field of fluid mechanics," Brenner said. "And I was fortunate to come to this early in my life. In high school, I had a difficult time in geometry, perhaps like many of you. But I had a wonderful teacher, Mr. Woods, who did a theorem proving that the interior angles of a triangle added up to 180 degrees. This was a purely theoretical exercise, one that I had never thought about before. It was hard to believe that you could use your own mind to predict something and then go into the world or the laboratory and measure it. I had a protractor because I was taking a course in mechanical engineering. After class I drew some triangles and they added up to 180 degrees and I was amazed. And I have been amazed ever since."

Howard is an extraordinary scholar. We wish him the best as an Emeritus Professor.

Beloved Events Coordinator Arline Benford Retires

Arline Benford addresses an army of well-wishers at her retirement party in Walker Lounge, July 25, 2005.

Much to the sadness of the Department, our beloved Arline Benford retired in the summer of 2005, after 23 years at MIT. Known for her never-ending exuberance and welcoming spirit, Arline was a favorite of students and faculty alike.

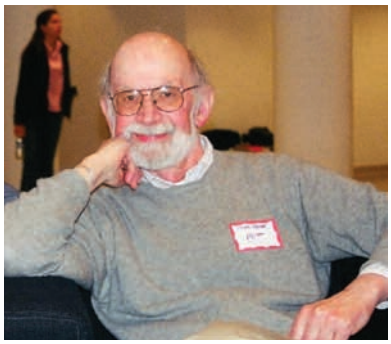
Arline worked in the Computer Science Department before coming to us in 1989. "I saw the light and went to ChemE where people are almost normal! ChemEs are fun and they have a great sense of humor – they're a nice group of people," Arline said of her colleagues and friends. "I'll miss this department and the good people here."

Over her 17 years in the Chemical Engineering Department, Arline worked for Professors James Wei and Bob Brown when they were department heads, as well as helping many other professors. She is also famous for organizing grand departmental events. Be it in San Francisco or Cincinnati, her welcoming smile was a regular highlight of the MIT reception at each national AIChE meeting.

Best wishes, Arline – we will miss you! ⊡

Bob Armstrong thanks Arline Benford for years of service at her retirement party in Walker Lounge, July 25, 2005.

In Memoriam



C. Michael Mohr (SB '55, ScD '61) 1932-2005

The Chemical Engineering Department has lost a dear friend, colleague, mentor and teacher. Dr. ***C. Michael "Mike" Mohr*** **(SB '55, ScD '61)**, a beloved MIT lecturer whose undergraduate students presented him with the annual Outstanding Faculty Award more than 10 years in a row, died of lung cancer on June 9, 2005, at Massachusetts General Hospital. He was 72 years old.

Dr. Mohr, a native of South Haven, Mich., lived in Melrose, MA. He had taught in the department as a senior lecturer for over 30 years, specializing in process synthesis, mathematical modeling and systems engineering. His dedication to his students arose both from enthusiasm for his field and empathetic awareness of the challenges facing young adults. Dr. Mohr's passing was reported in the June 10, 2005 Tech Talk. Below are excerpts.

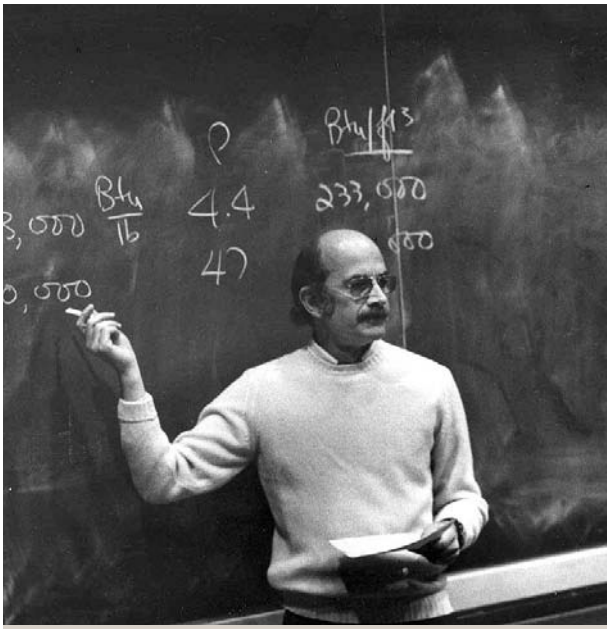
"Mike has a very warm spot in the hearts of all of the members of the department — students, staff and faculty. He was an incredibly effective and loved teacher, as evidenced by the steady stream of teaching awards that he received year after year. He was a primary contact and mentor for many of our undergraduates, and he cared deeply about their well-being as students and as young adults. It is very difficult to imagine the department without Mike," said Professor Armstrong.

In 1998, Dr. Mohr was presented the prestigious Baker Award for Excellence in Undergraduate Teaching by undergraduates and won the annual Big Screw charity fund-raiser award. He served as coordinator for the department's Undergraduate Research Opportunity Program (UROP), guiding students to — and through — their first laboratory research jobs. A tenor who sang with the MIT Logarhythms, the Institute's all-male a cappella group, as an undergraduate, he also served as a founding faculty advisor to the co-ed MIT Chorallaries.

"Teaching and only teaching was his life. He never repeated a lecture or a problem set. He took great pride in teaching and being accessible," said glass bead artist Martha Giberson, Dr. Mohr's wife of 23 years. In his singular supportive and humorous way, he helped guide generations of MIT chemical engineering students through their studies and careers. He is greatly missed.

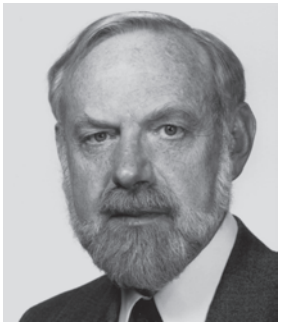
Based on a proposal by the Executive Committee of the AIChE Student Chapter, the department is recognizing Mike Mohr's extraordinary devotion to undergraduates by creating a fund to support UROPs in the department. The new fund is named the C. Michael Mohr (1955) Undergraduate Research Opportunities Program (UROP) Fund. The fund would be used preferentially to provide for UROP wages during the independent activities period (IAP) and summer terms, when the UROP is not being performed for credit.

Donations to this fund can be made by sending a check to the Chemical Engineering Department payable to MIT with a notation designating the contribution to this fund. You can reference either the fund name or the account number, which is 3159180.



Dr. Mohr teaches an undergraduate class in 1987.

ChemE Connection



Robert C. Reid (ScD '54) 1925-2006

The department regrets to announce the death of Professor Emeritus ***Robert C. Reid*** **(ScD '54)**, who died May 18, 2006, at Winchester Hospital. He was 81 years old.

Professor Reid retired from MIT in 1985 after 34 years at the Institute. In the June 7, 2006 Tech Talk, his former students, many of whom went on to careers in teaching and research, remembered him as an inspiring mentor.

Professor ***Jeff Tester*** **(PhD '71)** said that when he came to MIT as a PhD student in 1967, Professor Reid was the first professor he got to know extremely well, both inside and outside the classroom.

"I couldn't have had a better experience," he said, adding that many of his fellow former students felt the same way. "Many, many generations of people have benefited from Bob's mentoring."

Professor ***Ken Smith*** **(SB '58, ScD '62)**, another former student, said that Professor Reid "brought a fresh, outward-looking perspective to the department. He was a fantastic teacher and much loved by students in whom he showed an active and highly individualized interest."

He was also humble and thoughtful in his approach to engineering problems, said another former student, ***Elisabeth Drake*** **(SB '58, ScD '66)**, visiting engineer in the Laboratory for Energy and the Environment.

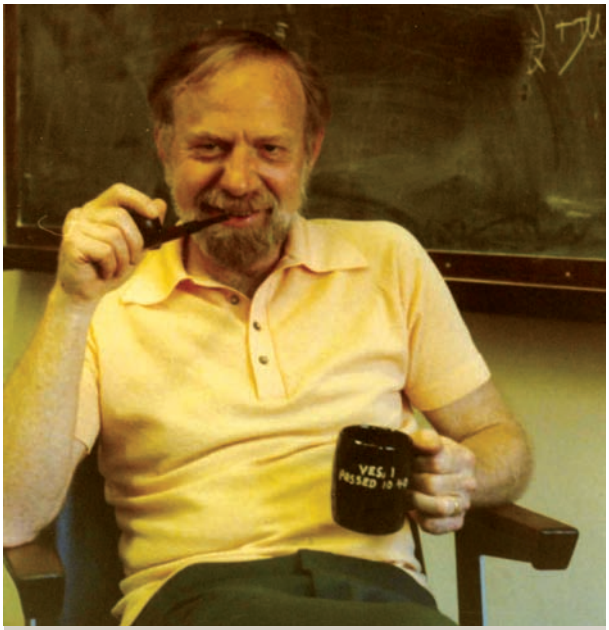
"Because he took time thinking about technical challenges, he often came up with unusual approaches that were very effective," she said. "He also took time to get to know his professional colleagues as people — it was always both challenging and fun to interact with him."

Professor Reid also liked to have fun with his classes, occasionally dressing up for a guest lecture as the great thermodynamicist Willard Gibbs, complete with 19th-century dress, wig and accent, Drake said.

Professor Reid earned bachelor's degrees in marine engineering from the U.S. Merchant Marine Academy and in chemical engineering from Purdue University. He earned a master's degree from Purdue and the ScD from MIT, both in chemical engineering.

Professor Reid co-wrote two important textbooks, *The Properties of Gases and Liquids* and *Thermodynamics and Its Applications*, and served as editor of *AIChE Journal*. He was director of AIChE from 1969 to 1971 and was a member of the National Academy of Engineering.

On October 13, 2006, the Chemical Engineering Department hosted a Symposium to Honor Professor Reid. For more information on the symposium, go to: **http://web.mit.edu/cheme/news/reid.html**

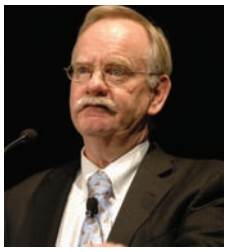


Professor Reid poses with an infamous "Yes, I passed 10.40" coffee mug.

Lectures and Events

In the Department of Chemical Engineering

Symposium to Honor Robert A. Brown: A Day of Reflections by Colleagues and Former Students



Friday, December 9, 2005

On the snowy afternoon of Friday, December 9, 2005, the MIT Chemical Engineering Department held a Symposium to honor ***Robert A. Brown***, now president of Boston University (see article on page 12), for his tremendous contributions through research, education, and service to MIT, to the profession of chemical engineering, and to the fields of fluid mechanics and crystal growth.

From 1:00 -5:30 PM, a technical symposium was held at MIT in Bartos Theatre (E15-070), featuring several reviews and projections about areas in which Dr. Brown has worked, given by his colleagues and former students. Professor ***Robert Armstrong***, along with two of Dr. Brown's former students, Professors ***Gareth McKinley*** **(PhD '91)**, now a professor of mechanical engineering at MIT, and ***Jeff Derby*** **(PhD '86)**, now at the University of Minnesota, helped organize this event.

December 9 was an especially snowy day, threatening cancellation of the event. Professor Armstrong simply joked that it was "only appropriate" that this symposium be during a snowstorm, since the day Dr. Brown came to MIT for his interview as a faculty candidate was during the infamous Blizzard of '78.

Speakers included Professors ***Lyle Ungar*** **(PhD '84),** ***Susan Muller*** **(PhD'86),** ***Talid Sinno*** **(PhD '98),** ***L. Gary Leal*****, and** ***François Dupret*****, Drs.** ***Bill Raiford*** **(PhD '89),** ***Tom Kinney*** **(PhD '92),** ***Dilip Rajagopalan*** **(PhD '91),** ***Indranil Ghosh*** **(PhD '00)**, and ***Ramesh Natarajan***. Their presentations ran the gamut of what they learned from Dr. Brown when he taught 10.32 and 10.50, reminiscing about the early years of the Athena system in the 1980s, to current work and skills based on Dr. Brown's research and teachings.

From Professor Derby's "All I Really Need to Know I Learned in Graduate School from Bob Brown" to Dr. Kinney's statement that "Bob is at the core of everything I've done since graduating – not just crystal growth, but beyond it," it was truly a day of tribute to and respect for all Dr. Brown as done at MIT.

For more information and to view the entertaining webcast of the Symposium, go to:
http://web.mit.edu/cheme/news/brown_event.html

About Dr. Robert A. Brown

Robert A. Brown, Ph.D., 10th president of Boston University, is a distinguished scholar of chemical engineering and an innovative leader in higher education. He assumed the presidency of Boston University in September 2005.

Dr. Brown, 54, a Texas native, earned a BS and an MS in chemical engineering at the University of Texas at Austin. He earned a PhD at the University of Minnesota.

Prior to his appointment at Boston University, Dr. Brown was provost and Warren K. Lewis Professor of Chemical Engineering at MIT. He is a member of the National Academy of Sciences, the American Academy of Arts and Sciences, the National Academy of Engineering, and numerous other prestigious professional societies.

In 1979, Dr. Brown joined the faculty of MIT as assistant professor. During the last 25 years, he advanced his scholarly and administrative career, serving as co-director of the MIT Supercomputer Facility, Head of the Department of Chemical Engineering, and Dean of Engineering. In 1998, Dr. Brown was appointed Provost of MIT.

Dr. Brown has published approximately 250 papers in areas related to mathematical modeling of phenomena associated with materials processing, fluid mechanics of viscoelastic fluids, interface morphology, and modeling of semiconductor processing. He has served as consultant to major international corporations and to governments. He was named a 2005 Honorary Citizen for his service to the government of Singapore.

During his tenure at MIT, Dr. Brown led the creation of multi-disciplinary research centers including the McGovern Institute for Brain Research; the Broad Institute, a world-renowned genomics research collaboration with Harvard University, its affiliated hospitals and the Whitehead Institute for Biomedical Research; and the development of the Ray and Maria Stata Center as a facility for teaching, research and student life focused on computer, information and intelligence sciences. Dr. Brown also oversaw the creation of the Biological Engineering Division and the Division of Engineering Systems as new interdisciplinary units in teaching and research.

Dr. Brown lives in Brookline, MA, with his wife Beverly, a health care professional with a doctorate in biochemistry. They have two grown sons.

Symposium to Honor Daniel I.C. Wang on the Occasion of his 70th Birthday

Saturday, April 22, 2006

In Spring 2006, a Symposium was held to recognize Institute Professor ***Daniel I. C. Wang*** **(BS '59, MS '61)**, for his research and educational contributions in the profession of chemical engineering and the field of biochemical engineering on the occasion of his 70th birthday. The symposium brought together over 150 participants from both academia and industry.

The day consisted of talks from former students and colleagues, each sharing a different "View" of Professor Wang's legacy. Along with research discussion, there were several tributes to Professor Wang. His love of fellowship with family and friends was a major theme, and the warmth and respect of his former students and colleagues was apparent.

In a move hearkening back to their days as Professor Wang's students, the symposium attendees formed Breakout Groups to discuss and present on five different areas of Professor Wang's research and work: Advances in Cell Culture, Bioseparations, Industrial Biotechnology, Enzyme Technology, and Education. The groups then presented their work to the master himself, Professor Wang.

Professor Wang's considerable contributions to the field of bioengineering are evidenced in the special October 2006 issue of "Biotechnology and Bioengineering: A Celebration of Daniel I.C. Wang at 70." Summaries of the five symposium breakout sessions are also in this issue.

For more information or to read articles in the tribute publication, go to: **http://web.mit.edu/cheme/news/dwang.html**

About Institute Professor Daniel I. C. Wang

Daniel I. C. Wang received his BS degree in Chemical Engineering in 1959 from MIT. He obtained his MS degree in Biochemical Engineering in 1961 also from MIT. He continued his studies at the University of Pennsylvania and received his PhD degree in chemical engineering in 1963. He served two years in the U.S. Army and returned to MIT as an assistant professor in 1965. Professor Wang founded the Biotechnology Process Engineering Center through the NSF Engineering Research Center Initiative and acted as its director from 1985 to 1998. He held the Chevron Professorship from 1985 to 1996. He was subsequently named as an Institute Professor of Chemical Engineering at MIT in 1996. In 2000, Professor Wang was given the Temasek Professorship at the National University of Singapore where he devotes part of his time to help Singapore in their biomedical science research and development. He received an honorary doctorate in engineering from the Hong Kong University of Science and Technology in 2000 and an honorary doctorate in engineering from the Catholic University Valparaiso, Chile, in 2002.

In 2004, his received honorary professorship from Peking Union Medical College, Beijing, China.

Professor Wang has received awards from the American Chemical Society (Marvin J. Johnson Award, and David Perlman Memorial Lecturer). Thirteen of his past graduate students have received the W.H. Peterson Award from the American Chemical Society for their outstanding papers at its annual meetings. He has also received awards from AIChE (Food, Pharmaceutical and Bioengineering Award, Institute Lecturer and William H. Walker Award). He was given the Amgen Award in Biochemical Engineering from the Engineering Foundation. He has also received the Asia-Pacific Biochemical Engineering Award. Professor Wang has received the Chemical Engineering Department's Outstanding Teaching Award three times.

Professor Wang has been elected to the American Academy of Arts and Sciences, National Academy of Engineering, American Institute of Medical and Biological Engineering, Academia Sinica (Republic of China) and International Institute of Biotechnology. He had been invited as Plenary and Opening Lecturer to a number of international conferences and symposia including countries such as the US, United Kingdom, Singapore, Malaysia, Thailand, Hong Kong, Australia, Taiwan, Japan, Korea, Germany, New Zealand, Italy, People's Republic of China, Chile, and Mexico. He has consulted for over 50 companies world-wide and is on the board of directors and scientific advisory boards on a number of public and private companies.

Professor Wang has authored and co-authored five books, over 230 publications, and 15 patents. He resides and has resided as editorial board members for eight scientific journals. His international activities include membership on the International Advisory Committee of the Biotechnology Research Institute of the Hong Kong University of Science & Technology, Strategic Review Board on Biotechnology (Chairman) in the Republic of China, International Advisory Committee of the National University of Singapore, Chairman of the Scientific Advisory Board (SAB) of the Bioprocessing Technology Institute, A*STAR of Singapore and a member of SAB for the Institute of Chemical and Engineering Science, A*STAR of Singapore. He is an honorary professor at the Zhejiang University, People's Republic of China.

Professor Wang has resided on the board of directors for a number public and private companies. At this time, he resides on the board of directors for three privately held companies.

Frontiers in Biotechnology Lecture

2005

"Drugs from Bugs: Production of an Antimalarial Drug in Microbes"
Professor ***Jay Keasling***
Professor of Chemical Engineering and Bioengineering Director, Berkeley Center for Synthetic Biology University of California, Berkeley

The research area of Professor ***Jay Keasling***, the 2005 Frontiers in Biotechnology Lecturer, is engineering micro-organisms for the environmentally friendly synthesis of small molecules or degradation of environmental contaminants. For his MIT lecture, Professor Keasling specifically discussed his work to produce an antimalarial drug through his microbial work.

Between 1.5 and 2.7 million people die of malaria each year; ninety percent of victims are children. The disease has an even wider affect than just its direct sufferers; economists have proposed that malaria decreases the GDP of affected countries by as much as fifty percent.

Professor Keasling explained that the plant-based malaria drug artemisinin is very effective against the disease, but it is too expensive for use in developing countries. Thus, the goal of his research group was to engineer a microorganism to produce artemisinin from an inexpensive, renewable resource. One of the major challenges of this project is to find a good "platform organism" with appropriate gene expression tools. Professor Keasling's team synthesized genes and mixed them from other plants, eventually creating a microbial strain that can produce amorphadiene, the precursor to artemisinin. With this precursor, the team can next synthesize artemisinin at a much lower cost than the original drug. The work is ongoing; Professor Keasling is working with Amyris Biotechnologies and the Institute for OneWorld Health, the world's first nonprofit pharmaceutical company, toward the goal of making the drug available in three to five years, at a cost of about 21 to 12 cents per dose (from its current $2.25 to $2.50).

For more information and to view the webcast of Professor Keasling's lecture, go to:
http://web.mit.edu/cheme/news/frontiers.html

About Professor Jay Keasling

Professor Keasling received his BS in Chemistry and Biology from the University of Nebraska in 1986; his PhD in Chemical Engineering from the University of Michigan in 1991; and did his postdoctoral work in Biochemistry at Stanford University from 1991-1992. Professor Keasling joined the Department of Chemical Engineering at the University of California, Berkeley, as an assistant professor in 1992, where he is currently professor.

Professor Keasling is also a professor in the Department of Bioengineering at Berkeley, a faculty scientist and Director of the Physical Biosciences Division at the Lawrence Berkeley National Laboratory, and Director of the Berkeley Center for Synthetic Biology. He has received several awards, including the CAREER Award from the National Science Foundation and the AIChE Award for Chemical Engineering Excellence in Academic Teaching, and has given several award lectureships, including the Inaugural Schwartz Lectureship at Johns Hopkins University and the Allan P. Colburn Memorial Lectureship at the University of Delaware. Professor Keasling's laboratory has engineered microorganisms to produce polymers and the anti-malaria drug artemisinin, as well as to accumulate uranium and to degrade nerve agents. He is also a founder of two companies, Amyris Biotechnologies and Codon Devices; both grew out of discoveries from his laboratory.

The **Frontiers in Biotechnology Lectureship** was established in 1999 to recognize fields that complement the biological sciences and help to make biotechnology such a robust and exciting area in which to work. Through a generous donation from Dr. ***Noubar Afeyan*** **(PhD '87)**, we can acknowledge the enabling technologies and developments that have sustained the growth of biotechnology and life sciences. Some of these include bioprocess engineering (upstream and downstream processes), bioanalytical developments, advanced and new instruments, novel delivery concepts, biomedical devices, rational drug design, computational methods, bioinformatics, and information technology. It is the intent of this Lectureship to recognize and honor achievements on the "frontiers of biotechnology" and the distinguished scientists and engineers responsible for them.

Warren K. Lewis Lecture

2006

"Engineering by Evolution"
Professor ***Frances Arnold***
Dick and Barbara Dickinson Professor of Chemical Engineering and Biochemistry
California Institute of Technology

During the week of February 13, 2006, the Department was honored to host Professor ***Frances Arnold***, the 2005 Lewis Lecturer. On Wednesday of that week, she presented her research in a seminar entitled "An Artificial Protein Family Created by Structure-Guided Recombination."

Professor Arnold explained that her research is investigating ways in which proteins can be "recombined to create new proteins with desirable properties. This approach circumvents our profound ignorance of how the amino acid sequence encodes protein function and exploits the ability of biological systems to evolve and adapt. Computational tools assist the experimental search for new proteins by identifying elements of structure that can be swapped among related proteins while minimizing structural disruption. Structure-guided recombination of homologous proteins generates libraries of diverse sequences, a large fraction of which retain the parental fold. We have used this approach to make a library comprising thousands of properly-folded cytochromes P450 which differ from their bacterial parents by up to 101 amino acid substitutions. High throughput sequencing and functional analysis of the resulting proteins has produced a large dataset which, unlike natural sequences, includes unfolded and nonfunctional sequences in addition to sequences with nonnatural functions. Besides providing new insights into what it takes to make a functional cytochrome P450, free from many of the filtering effects of natural selection, these laboratory-generated enzymes exhibit interesting and useful new activities, including the ability to produce the authentic human metabolites of drugs."

On Friday, February 15, 2006, we heard Professor Arnold's broader topic of "Engineering by Evolution." She began her talk with a tribute to Professor Lewis, reminding the audience that "we as chemical engineers practice – we build things. And if we do it well, we do it based upon sound fundamentals. This is something that has guided MIT and many other departments that have followed in MIT's footsteps."

Professor Arnold delved into the complex world of bioengineering, explaining its beginnings and going through some of the work being done today. Biological engineering through the years has expanded to include protein engineering, metabolic engineering, and synthetic biology, which has "appeared to subsume these earlier efforts" and has the complex goal to reprogram whole living organisms and make new forms of life. This evolution through engineering is exciting, but also difficult. Engineers build codes to control cell activity, but the cells may fight this through mutation and other activity. "This isn't bricks and mortar," she explained, "we're dealing with something that has a life… We have to learn new principles on how to control their behavior."

Human design of cells to maximize their behavior is difficult, but the natural evolution of cells through thousands of years of adaptation and natural selection has obviously been very successful. Biological systems, as products of evolution, are readily evolvable in the laboratory; biological engineering works to simulate this process. Professor Arnold explained that unfortunately, evolution is also difficult. Through a series of examples, Professor Arnold showed how biological engineers have been able to optimize cellular "parts" and systems through directed evolution. She summarizes, "Biology is unique among engineering substrates… Evolution can rescue, and improve, less-than-perfect (but good-as-you-can-get) [human] designs."

For more information and to view the webcast of Professor Arnold's lecture, go to:
http://web.mit.edu/cheme/news/lewis.html

About Professor Frances Arnold

Frances Arnold is the Dick and Barbara Dickinson Professor of Chemical Engineering and Biochemistry at the California Institute of Technology. Her research group engineers enzymes, biosynthetic pathways, and genetic regulatory circuits by directed evolution.

Professor Arnold has co-authored more than 200 publications and edited several books on protein engineering and laboratory protein evolution. A member of the National Academy of Engineering and the Institute of Medicine of the National Academies, she has served on the Science Board of the Santa Fe Institute and the Science Advisory Boards of several corporations. Her recent awards include the Olin-Garvan Medal of the American Chemical Society (2005), the Food, Pharmaceuticals and Bioengineering Division Award of the AIChE (2005), the David Perlman Memorial Lectureship of the ACS Biochemical Technology Division (2003), the Carothers Award from the Delaware ACS (2003), and the Professional Progress Award of the AIChE (2000). She has more than 25 patents issued or pending.

After receiving her BS in mechanical and aerospace engineering from Princeton University in 1979, Professor Arnold worked at the Solar Energy Research Institute in Golden, CO. She completed her PhD in chemical engineering at the University of California, Berkeley, in 1985. Following postdoctoral research in chemistry at Berkeley and the California Institute of Technology, she joined the faculty of Caltech's Division of Chemistry and Chemical Engineering in 1987. She and her husband, Andrew Lange (Caltech, Physics), have three sons, ages 8, 9 and 15.

For Professor Arnold's research and publications, see:
http://www.che.caltech.edu/groups/fha

The **Warren K. Lewis Lectureship** was established in 1978 to recognize Professor Lewis's revolutionary impact on chemical engineering education. One of MIT's first students in chemical engineering, he made seminal impact to the discipline. By developing the concept of unit operations, first proposed by A. D. Little and William Walker, he revolutionized the design of chemical engineering processes and equipment. Throughout his career, Professor Lewis was mindful of the needs of industrial practice; accordingly, the Lewis lecture features speakers from industry and academia.

Alan S. Michaels Distinguished Lectureship in Medical and Biological Engineering

2006
"Engineering Novel Medical Aerosols for Global Health"
Professor ***David A. Edwards***
Gordon McKay Professor of the Practice of Biomedical Engineering
Harvard University

Professor ***David A. Edwards***, a former postdoctoral assistant in the Chemical Engineering Department who worked with Professors ***Howard Brenner*** and ***Bob Langer***, presented the 2006 Alan S. Michaels Lecture on Friday, April 21, 2006.

Professor Edwards explained that airborne infectious disease is a major global health threat – millions die from it each year. His work focuses on the engineering of novel medical aerosols for treatment, vaccination and infection control using simple sprays. Professor Edwards reviewed the basic science, commercial translation and clinical development of aerosols and discussed how these aerosol particle designs can be used through nonprofit and for-profit entities to treat problems of global health, like tuberculosis.

He discussed the four technology platforms that have been developed: large porous particle (LPP) aerosols, which are in late stage clinical trials; porous nanoparticle aggregated particles (PNAP); dry membrane particles (DMP), a new technology that has not yet been published; and anti-infectious aerosols (AIA).

For more information and to view the webcast of Professor Edwards's lecture, go to:
http://web.mit.edu/cheme/news/michaels_2006.html

About Professor David A. Edwards

David A. Edwards is the Gordon McKay Professor of the Practice of Biomedical Engineering at Harvard University. Prior to joining the Harvard faculty in January 2002, Professor Edwards held teaching and research positions at MIT and the Technion (Israel) (1987-1995). From 1995-98 he served as an associate professor of chemical engineering at Penn State University.

In 1997 Professor Edwards co-founded Advanced Inhalation Research (AIR) (now part of Alkermes, a publicly traded pharmaceutical company in Cambridge) based on his scientific discovery of a new therapeutic aerosol drug form. From 1998 to 2001 Professor Edwards served as Chief Scientific Officer at AIR, helping to initiate its two most advanced products currently in the clinic, inhaled insulin and inhaled growth hormone, both in Phase III testing with Eli Lilly and Co. At Harvard University Professor Edwards develops novel medical technologies for improved healthcare treatment in the developing world.

In the summer of 2002 he formed the international not-for-profit, Medicine in Need (MEND) (**www.medicineinneed.org**), aimed at translating advanced drug delivery approaches toward the development of new treatments of diseases of poverty, and presently based in Cambridge (USA), Paris (France), and Pretoria (South Africa). In the spring of 2003, he co-founded the startup company Pulmatrix (**www.pulmatrix.com**), aimed at developing a novel approach to mitigating the spread of inhaled infectious diseases, such as tuberculosis and avian influenza.

Professor Edwards is a member of the National Academy of Engineering and the recipient of numerous national and international awards, including the Ebert Award of the American Association of Pharmaceutical Scientists (1995, 1996, 1999), the Herzl Award of the Municipality of Jerusaleum (2000), the AIChE Professional Progress Award (2002), and the Third Annual Pharmaceutical Research Awards' American Scientist of the Year Award (Finalist) (2004). He is a Bill and Melinda Gates Grand Challenge grantee for his research toward needleless vaccines for children in developing world nations.

The **Alan S. Michaels Distinguished Lectureship in Medical and Biological Engineering** was established in 1995 to stimulate the collaboration of the medical profession, life sciences industries, and chemical engineering researchers.

The most exciting and promising developments in medicine and the life sciences - those leading to improved therapies for the treatment or mitigation of intractable diseases, and strategies for prevention of debilitating or life-threatening genetic deficiencies - are largely emerging from discoveries in molecular biology and biochemistry, in concert with those in the sister-sciences of immunology, pharmacology, and genetics. These developments involve, in a very direct way, the basic tools that are the hallmark of the chemical engineer's profession: molecular thermodynamics, chemical reaction kinetics, homogeneous and the heterogeneous catalysis, fluid mechanics, and mass- and energy-transport processes.
Few other engineering disciplines are as well qualified to deal with the microscopic and molecular phenomena affecting living systems.

Hoyt C. Hottel Lecture in Chemical Engineering
2006

"Our Energy Future: Why American Science and Engineering Must Lead the Way" The Honorable ***Samuel W. Bodman*** **(ScD '65)** U.S. Secretary of Energy

On Tuesday, May 9, 2006, in front of a packed audience, U.S. Secretary of Energy, MIT Course X alumnus and former MIT chemical engineering professor ***Sam Bodman*** **(ScD '65)** gave the Hoyt C. Hottel Lecture, co-sponsored by the Chemical Engineering Department and newly created Energy Research Council. Secretary Bodman was frank and engaging in his discussion of alternative fuel sources and the state of the country's energy usage today. Below are excepts from the May 7, 2006 Tech Talk coverage of the event.

Secretary Bodman said high prices at the pump are on everybody's mind and that the current administration will oppose additional gasoline taxes. "Working families are already struggling under high prices," he said. "I don't think (they're) likely to see enthusiasm for increasing gas prices even higher."

The $23 billion budget of the U.S. Department of Energy will undergo major reshuffling if the Bush administration succeeds in getting its proposed changes through Congress, Secretary Bodman stated. While the overall annual budget will not increase, he said the part of the budget devoted to alternative fuels, hybrid vehicles, solar and wind energy, fuel cells and coal as a clean fuel source will increase 22 percent in fiscal 2007.

Nuclear power must play a larger role as a future energy source, Secretary Bodman said, and building the new plants to increase its role will take years and cost billions of dollars. The Bush administration has asked Congress for $250 million in 2007 to launch the Global Nuclear Energy Partnership to help meet growing global energy demand, but a repository for nuclear waste needs to be found, and nuclear waste needs to be reduced overall and made less radioactive to pave the way for a new generation of plants.

For more information and to view the webcast and transcript of Secretary Bodman's lecture, go to:
http://web.mit.edu/cheme/news/hottel_2006.html

About Secretary Samuel Wright Bodman

Samuel Wright Bodman became the 11th Secretary of Energy upon a unanimous confirmation by the United States Senate on February 1, 2005. He leads the Department of Energy with a budget in excess of $23 billion and over 100,000 federal and contractor employees.

Previously, Secretary Bodman served as Deputy Secretary of the Treasury beginning in February 2004. He also served the Bush Administration as the Deputy Secretary of the Department of Commerce beginning in 2001. A financier and executive by trade, with three decades of experience in the private sector, Secretary Bodman was well suited to manage the day-to-day operations of both of these cabinet agencies.

Born in 1938 in Chicago, he graduated in 1961 with a BS in chemical engineering from Cornell University. In 1965, he completed his ScD at MIT. For the next six years he served as an associate professor of chemical engineering at MIT and began his work in the financial sector as Technical Director of the American Research and Development Corporation, a pioneer venture capital firm. He and his colleagues provided financial and managerial support to scores of new business enterprises located throughout the United States.

From there, Secretary Bodman went to Fidelity Venture Associates, a division of Fidelity Investments. In 1983 he was named President and Chief Operating Officer of Fidelity Investments and a director of the Fidelity Group of Mutual Funds. In 1987, he joined Cabot Corporation, a Boston-based Fortune 300 company with global business activities in specialty chemicals and materials, where he served as chairman, CEO, and a director. Over the years, he has been a director of many other publicly owned corporations.

Secretary Bodman has also been active in public service. He is a former director of MIT's School of Chemical Engineering Practice and a former member of the MIT Commission on Education. He also served as a member of the Executive and Investment Committees at MIT, a member of the American Academy of Arts & Sciences, and a trustee of the Isabella Stewart Gardner Museum and the New England Aquarium.

Secretary Bodman is married to M. Diane Bodman. He has three children, two stepchildren, and eight grandchildren.

The **Hoyt C. Hottel Lectureship** was established in early 1985 to recognize Professor Hottel's contributions to the intellectual climate of the Chemical Engineering Department, to the encouragement of students over six decades, and to the foundation and direction of the Fuels Research Laboratory. The lectureship is intended to draw eminent scholars to MIT - preferably in the fields of combustion and energy technology - for short periods of residency in order to stimulate future generations of students. The inaugural Hottel Lecture was presented in April 1985 by Professor Hottel himself.

From the Head of the Department

Professor Robert C. Armstrong from page 1

Klavs' long list of honors include membership in the National Academy of Engineering, Fellow of the Royal Society on Chemistry, London, honorary doctorate from the Danish Technical University, a Guggenheim Fellowship, and the distinguished R.H. Wilhelm, Allan P. Colburn, and Charles M.A. Stine Awards from the American Institute of Chemical Engineers, and the Camille and Henry Dreyfus Teacher-Scholar Award. We all look forward to many years of Klavs' leadership.

As outgoing head, I would like to reflect briefly on my tenure. For most of the past ten years we have not had many faculty openings, so the amount of faculty hiring we have done has been modest. But those we have hired have been great additions to the department, who I think will be vitally important in helping us to continue our dominance of chemical engineering. Alas we have lost some great ones as well - two departmental faculty members, ***Bob Brown*** and ***Alice Gast*** (see articles on Pages 12 and 8), to university presidencies in one year has to be a first!

Credit for these achievements certainly goes to the faculty members of the department, who generate the new ideas, formulate new curricula and programs, teach our students, bring in research volume, recruit the best students and new faculty, and win honors and awards. They are a fantastic group, and I have thoroughly enjoyed working with them as head. Equally important to our successes are the outstanding students, postdocs, and staff who make this such a great place to work.

I appreciate that I am an incurable optimist, but I sincerely believe that the future holds great promise and opportunities for the department and for the field of chemical engineering. It is important that we continue to look forward, rather than backwards, as we define and articulate this future to the world.

To be sure, there are challenges - two principal ones - that I think we must deal with effectively in order to be successful going forward. First is a natural tendency to become complacent after so many years at the top of our field. We need never to let ourselves get too comfortable with where we are, but rather strive continually to reinvent ourselves as we define the future of the discipline and to demand excellence from ourselves. Second is the set of centrifugal forces that seem to be inherent in the image of chemical engineering at the center of modern technology. It is, of course, appropriate and necessary for individual faculty members in the department to connect and interact with other partner disciplines needed in our research. However, we all need to balance those outward interactions with constant attention to our home department and roots, so that chemical engineering remains a vibrant discipline for the future. This is a balancing act that demands attention and commitment from all of us.

A significant part of my new life will revolve around energy. Over the past two years, I have been very busy helping to define MIT's future role in addressing the world's energy crisis as co-chair of the Energy Research Council. I have recently been appointed to serve as associate director of the new MIT Energy Initiative (MITEI) and will be very focused on the launch of a very ambitious program over the coming months and years. Clearly energy is an issue of great importance and opportunity for chemical engineering, and I look forward to our department's continuing its long tradition of innovation and contribution in this area. For more about MIT's Energy Initiative, please see **http://web.mit.edu/erc/**.

With the academic year that ended in June of 2006, we again produced outstanding graduates at both the undergraduate and graduate degree levels. We awarded 57 SB degrees in Chemical Engineering, 60% to women. The 57 bachelors degrees awarded this year represent the increasing size of our undergraduate class. This year's sophomore class size is 95. Also, during the 2005-2006 academic year, we granted 40 master's degrees in Chemical Engineering (most of those in the Practice School) and 32 doctorates.

For this coming fall we admitted over 57 new graduate students to study in one or both of the Practice School and doctoral programs. The quality of the students is excellent, as measured by the large number of applicants to our program, the high degree of selectivity exercised in our admissions process, and our unusually high yield (percentage of admitted students who accept our offer). We are grateful to Professor ***Paula T. Hammond*** and the graduate admissions committee for their hard work in bringing in these outstanding students.

An essential asset in our effort to attract the very best students to our Department is the generous external support to the Practice School and our doctoral program by our alumni, through endowed and continuing support of graduate fellowships. We are truly indebted to you for your ongoing commitment and support. Beyond its value as a recruiting tool, funds for graduate fellowships are an essential element of our graduate educational philosophy.

By targeting fellowship support on Practice School students and beginning doctoral students, we can have these students begin their graduate program focused on the core subjects of chemical engineering. This not only provides all students with in-depth study of fundamentals that underlie whatever specialty they pursue in chemical engineering, but also provides doctoral students the important opportunity to learn more about the breadth of research opportunities in the Department before choosing a thesis topic. This model for educating graduate-level

From the Head of the Department

chemical engineers goes hand-in-hand with the picture of modern chemical engineering as the central engineering discipline embraced by our Department.

Since the previous Newsletter, there have also been several significant changes in the faculty to bring to your attention, especially in the areas of tenure and promotion. Effective July 2005, Professor ***Paul Barton*** was promoted to full professor, Professor ***Bernhardt Trout*** was granted tenure, and Professor ***Patrick Doyle*** was promoted to associate professor without tenure. At the beginning of this academic year, Professor ***Paula Hammond*** was promoted to full professor. We are very proud of the accomplishments of these important members of our Department, and you can find more details on each of them later in this newsletter.

We have also added several new members to the departmental faculty over the past year and a half. In the fall of 2005 we were delighted to have ***Arup Chakraborty*** join us as the Robert T. Haslam Professor of Chemical Engineering. This past May, ***Narendra Maheshri*** joined the department as an Assistant Professor.

Over this same period of time we have also lost several key faculty members. As I mentioned, Professor ***Robert Brown*** left to assume the Presidency of Boston University; and Professor Alice Gast, the Presidency of Lehigh University. Professor ***Jackie Ying*** left to become Director of the Institute for Bioengineering and Nanotechnology in Singapore. After over 50 years of teaching as a chemical engineering professor, Professor ***Howard Brenner*** has retired, and is now enjoying the life of an emeritus professor. We are very sorry to lose these key contributors to our department and to MIT.

This past year, the department also lost a great friend, colleague, mentor, and teacher, Dr. ***C. Michael Mohr***. Mike has a very warm spot in the hearts of all of the members of the department—students, staff and faculty. He was an incredibly effective and loved teacher, as evidenced by the steady stream of teaching awards that he received – he had won our Outstanding Faculty Award more than 10 years in a row. Mike was a primary contact and mentor for many of our undergraduates, and he cared deeply about their wellbeing as students and as young adults. It is very difficult to imagine the Department without Mike. In his memory, we have created the C. Michael Mohr (1955) Undergraduate Research Opportunities Program (UROP) Fund, at the urging of our undergraduates. The fund will be used to support a deserving undergraduate in his or her first laboratory research project here at MIT. I invite you to help continue Mike's spirit of dedication to our students by contributing to the Mohr UROP Fund.

Equally sad was the loss of Emeritus Professor ***Robert C. Reid*** in May. Bob was an active member of the faculty for 31 years before retiring in 1985. Bob had a huge impact on the department and the profession. He was particularly well known for his contributions to methods of computing physical properties and the understanding of boiling heat transfer between immiscible liquids. Generations of students have known him for 10.40 and the thermodynamics text he co-authored. Among other memories, I remember Bob for the personal touch he brought to the department. Some of you may recall the "personal profiles" he created weekly by interviewing different members of the department; these were posted along with a charcoal sketch that he drew. We held a symposium at MIT in Bob's honor on the afternoon of October 13, 2006. Bob loved trees, and I am pleased to say that there is a red leaf Japanese maple by the entrance to building 66 that was planted in his memory.

And finally, our faculty members continue to distinguish themselves, and the past year and a half has produced another extensive list of faculty honors and awards. To name just a few notable achievements, in 2005 Professor ***Robert S. Langer*** received the Von Hippel Award from the Materials Research Society, the Albany Medical Center Prize in Medicine and Biomedical Research, and the Dan David Prize; and in 2006 he received honorary doctorates from the Albany Medical College and Northwestern University. Professor Alice Gast received the 2006 ACS Award in Colloid and Surface Science, Professor ***Robert Cohen*** was elected a Fellow of AIChE (2005) and received the inaugural MIT Capers and Marion McDonald Award for Excellence in Mentoring and Advising (2006), In 2006 Professor ***Klavs Jensen*** was recognized with the Doctor Technices Honoris Causa from DTH, and Professor ***Gregory Rutledge*** was elected Fellow of APS. Professor ***Kristala Prather*** Jones received an ONR Young Investigator Award in 2005. In addition to these, Professor ***Emeritus Larry Evans*** has become president of our professional society, AIChE, effective January 1, 2007.

I hope that you enjoy this issue of the newsletter, and I encourage you to write us to let us know how you are doing. Thank you all for your support and I wish you the best!

News from Alumni

Allan H. Bergman **(SM '58)** retired six years ago as corporate vice-president, Latin America, Adhesives/Specialty Polymers for National Starch and Chemical Company. He lives in Longboat Key, FL, for seven months of the year and in Short Hills, NJ, for five. Life in Longboat Key is good; he plays tennis 4-5 times a week and spends time on the beach. While in New Jersey, he goes to New York City often for theatre, music and restaurants. He is enjoying his hard earned retirement.

Congratulations to ***Chau-Chyun Chen*** **(ScD '80)**, who was elected to membership of the National Academy of Engineering in 2005. Chau-Chyun is a senior technology fellow at Aspen Technology Inc. in Cambridge, Mass. He was cited for "contributions to molecular thermodynamics and process-modeling technology for designing industrial processes with complex chemical systems."

Peter Farrell (SM '67), chairman and CEO of ResMed Inc., was Ernst & Young's 2005 Entrepreneur of the Year in Health Sciences

Peter Farrell **(SM '67)**, chairman and chief executive officer of ResMed Inc., was named the Ernst & Young Entrepreneur of the Year 2005 national award winner in the Health Sciences Category. Based in San Diego, ResMed's principal manufacturing operations focus on a machine that helps people suffering from sleep-disordered breathing and its most common cause, obstructive sleep apnea (OSA). ResMed's device offered the first successful noninvasive treatment of OSA.

Farrell, an Australia native, was well-ensconced in academia as chair of biomedical engineering at the University of New South Wales when industry lured him away. He joined Baxter Healthcare as director of its Japanese subsidiary and vice-president of research and development. When Baxter Healthcare decided not to pursue a developed technology to address sleep disordered breathing, Farrell organized a management buyout of Baxter's sleep technology, creating ResMed to develop and manufacture the devices.

William S. Foulks, **Jr. '42** was elected a Fellow of the Ohio Academy of Science, based in Columbus, OH. Fellows are selected for rendering a special service to the Academy or for extensive and productive scientific, technological or educational contributions to society.

Ben D. Halpern **'43** has retired after a long professional career which included being director of research at Borden Chemical Company and time at the start-up Monomer-Polymer, Inc., as well as Polysciences, Inc. Ben (also known as David) admits he is only semi-retired, as he consults in the field of specialty chemicals and medically related polymers and devices. He and his wife Ruth live in Rydal, PA, and enjoy visits to and by their four children. Family, elderhostels, travel, gardening, theater, and swimming keep them fully occupied.

Thomas M. McCarthy **(MS '52)** has a growing consulting practice in the waste-to-energy field and in biogas utilization. This is his second career and he has no intention to retire. He states, "Being involved with technology is fun, as is learning something new everyday." Thomas is based in Limal, Belgium.

Following his graduation, ***José Manuel Otero*** **'01** was hired as a staff biochemical engineer by the Fermentation & Cell Culture Department, Bioprocess Research & Development, Merck Research Labs. He initially worked on process development of the adenovirus based HIV vaccine. Approximately one year into his work, he joined the fermentation group and worked on process development of Merck's HPV vaccine, GardasilTM. In 2005, he was promoted to research biochemical engineer, and was also awarded a Merck doctoral fellowship. Under supervision of Professors Lisbeth Olsson and Jens Nielsen, he is workings towards his PhD in biochemical engineering and biotechnology at the Center for Microbial Biotechnology, BioCentrum, Technical University of Denmark (Kgs. Lyngby, Denmark). He is investigating metabolic engineering and systems biology strategies in Saccharomyces cerevisiae to over express succinic acid. Lastly, he says he is "fortunate enough to have found love in my life… I am engaged to my long-time girlfriend, Stephanie M. Praster (Course 2 BS '02)." Stephanie is a captain in the U.S. Air Force as a B1-bomber navigator. José and Stephanie were married in September 2006 in New York City.

Adam Louis "Lou" Shrier **(SM '60)** has been appointed Adjunct Professor in the Department of International and Public Affairs at Columbia University. In the spring of 2005, he designed and taught a graduate course on "The Geopolitics of Energy", which was offered again during the 2005-06 Academic Year. Shrier continues to advise companies and governments on investing in transition economies. In June 2005, he reviewed opportunities in Vietnam, and presented a paper

at an economics conference in Taiwan on the implications for the international oil industry of China's energy security policies.

Clyde Smith **(MS '35)** writes that in spite of a few ailments, he is ok for being 93! Most of his contacts are by email.

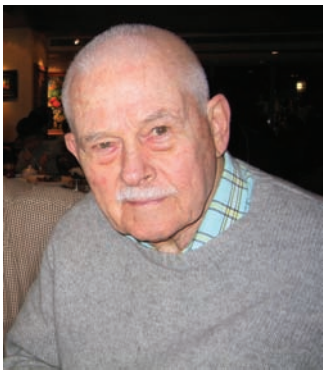
Pieter Stroeve **(ScD '73)** spent his 2004 sabbatical at the Wageningen University and Research Centre in the Netherlands. He conducted research in bionanotechnology and gave seminars in the subject. Pieter is a professor at the University of California, Davis.

Al Tobin **'60** has come full circle in his career. After 30 years working for Grumman Aerospace in the corporate research center as a materials scientist, he retired seven years ago to become an Adjunct Professor of Materials Science and Engineering at Stony Brook University. He is now teaching Chemical Engineering Thermodynamics to undergraduates.

Paul Yelvington **(PhD '05)** has joined Aerodyne Research Inc., Billerica, MA, as a Senior Engineer in the Center for Aero-Thermodynamics, where his research focuses on understanding gaseous and particulate emissions from combustion sources.

Freshly minted members of the Cardinal and Gray Society reminisce with Professor Bob Armstrong a the 2005 Chemical Engineering Alumni Reception.

In Memoriam



Charles Parker Marion (ScD '52) 1920-2005

Dr. *Charles P. Marion* (ScD '52), died peacefully on the morning of August 23, 2005, at Alterra Wynwood residence in Madison, WI, at the age of 85.

Born in Montclair, NJ, Charles was raised in southern California, where he was a graduate of Hollywood High School and UCLA. Charles met his sweetheart Jane in high school, and they were married in 1943 while he was training as a naval aviator during World War II. He served as flag lieutenant on the USS Boxer in the occupation forces of Japan, and flew carrier-based propeller and, later, jet fighter planes. After the war, he continued to serve the nation as an instrument flight instructor at Los Alamitos, CA, and ultimately reached the rank of Captain, USNR.

With the help of the GI Bill, Charles returned from the war to complete his degree at UCLA in 1947 and to study at MIT, where he received his doctorate in chemical engineering in 1952. He and Jane began their family while living in MIT's graduate student housing in Cambridge, MA.

After completing his graduate studies, Charles joined The Texas Company (Texaco), moved back to California, and worked for the next ten years at its research lab in Montebello, CA. In 1962, he moved the family to Mamaroneck, NY, where he worked with Texaco Development Corporation. in Manhattan and Harrison, NY, to license, install and operate the processes that he and his colleagues had developed at Montebello. Charles was a leader and innovator in partial oxidation and coal gasification technologies, and during his time with Texaco was inventor or co-inventor in more than fifty patents. He retired as Chief Technologist in 1985. This work took him all over the world. In addition to English, he read and spoke German and Spanish.

Charles and Jane lived together in Mamaroneck until she died in December 1998. Charles continued to live in NY until September 2002, when he began "commuting" between his sons' homes in Madison and Hong Kong. Despite his ever-encroaching Alzheimer's disease, he enriched their lives with his interest and encouragement, partaking as always in the joys of his grandchildren as they grew, graduated from high school and college, and began their lives as adults. Charles spent his final year in Madison, gradually losing strength and focus, but sharing his love and respect for all who knew him.

The family welcomes communications directly to the addresses below, and would love to receive your remembrances, stories or images of their dad.

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Howard S. Stern (SB '53, SM '54) 1931-2005

The department regrets to announce the death of ***Howard S. Stern*** **(SB '53, SM '54)**, who passed away on December 28, 2005, after fighting a brave battle with brain cancer. He was 74.

Howard was a beloved friend of the department and MIT; he will be greatly missed. He was also co-founder, Chairman Emeritus, and serving director for E-Z-EM, a leading manufacturer of contrast agents for gastrointestinal radiology. Below is a memorial to their colleague and friend:

"Howard was a giant in the industry, a true visionary, and a guiding light for all who had the privilege to work with him at E-Z-EM. For over 40 years, this Company grew under his stewardship to become an industry leader and play an important role in advancing treatments for cancer and other diseases of the digestive tract. Howard's passing is a great personal loss to all of us at E-Z-EM, who lost a colleague, a friend, and a father. We celebrate his life and are committed to continuing his legacy. Our thoughts and prayers are with the Stern family," said Anthony A. Lombardo, president and CEO of E-Z-EM.

Howard contributed many innovations to the field of radiology in his more than 40 years of leadership with E-Z-EM, in the process establishing the company as a recognized name among radiologists around the world. As Lombardo stated, "Howard dedicated his life to developing and producing medical products that improved healthcare treatment for patients. His desire to improve the methods for the screening and diagnosis of colon cancer was relentless, and his passion to encourage everyone to be screened was never ending."

Stern's significant contributions and incredible generosity reached far beyond his own family and the family of E-Z-EM. He was also active in many charitable causes, particularly at MIT, where he endowed a fellowship chair at the School of Chemical Engineering Practice, and supported the Center for Cancer Research. He also was the founding donor of the Center for Patient Partnerships at the University of Wisconsin-Madison, and also served on the board of trustees of the Parker Jewish Institute for Health Care & Rehabilitation. In honor of his father, he established the Isadore N. Stern Scholarship of the American Society of Radiologic Technologists (ASRT) Education and Research Foundation.

In 2001, in recognition of his life's work, Stern was honored with a special award by the Society of Gastrointestinal Radiologists (SGR), "in appreciation for his generous support and dedication to the educational mission of the Society."

From very humble beginnings, Stern was able, through vision, perseverance and heart to help change and affect the medical industry and the lives of countless people. His impact will continue to be felt for years to come.

In 1959 at a dinner party, Stern was listening to Dr. Phillip heard about a cross-contamination problem in patients receiving barium enemas before x-ray exams of their lower intestinal tracts, discussed by Dr. Philip Meyers. At that time, enemas were given from a bucket loaded with barium through a non-disposable tube and rectal tip. Stern, then a marketing director for a tiny radiation applications firm, posed a career- and, eventually, industry-changing question, "Why not make bags that are disposable?"

With Meyers's help, Stern bought a 100-lb barrel of barium sulfate and some cheap polyethylene and began making bags at home that he sealed with his mother's iron. The biggest challenge was how to mix barium sulfate with water inside the bag. Stern, ever the innovator, soon discovered it could be kneaded in the bag after water was added. Any small lumps of sulfate left could be caught by a filter device, which the pair then designed. The first crude kit was completed in 1960.

Since these homemade bags would not be sufficient in a hospital setting, Stern found a manufacturer of inflatable vinyl toys who was happy to make the bags for him. A maker of fishing lures was talked into making the rectal tips. With new samples ready, Stern and Meyers went to the Fugeta Co., hoping to sell the patented idea for royalties. But Fugeta passed, after distributing 500 kits free to the hospitals, stating the market just wasn't big enough.

How wrong they were. Stern, who once modestly stated that he "wasn't a risk taker", and Meyers each put up a $1,000 and went into business in 1962. This was the same year that a major radiology magazine carried three separate articles (one of them written by Meyers) on the contamination problem. Howard took over a 12-by-5 foot room in his father's garment factory loft in New York City. His mornings consisted of making up to 100 bags, and his afternoons were spent on the road making deliveries and knocking on doors. The first few years were tough. Howard scheduled his business trips primarily in Detroit, Philadelphia and Boston because he had friends he could stay with in those cities. In typical humorous fashion, he once joked, "I was the biggest mooch going."

Stern soon discovered that some radiologists were using his barium sulfate for oral examinations as well. Ever the entrepreneur, Stern began selling barium sulfate in various flavors without the bags. In 1964, he moved his operations to a 2,000 square foot plant on Long Island after landing a big contract to make bags for a major pharmaceutical company on a private-label basis.

During the next few years the Company saw its share of ups and downs, culminating in the difficult loss of a major contract in 1968. At first things seemed rather bleak, but Stern once again rose to the occasion. He recommended switching gears and stressing service by providing more specialty orders to the radiologists. For the company's first quarter-century, over 90% of revenues came from providing powdered and liquid barium sulfate mixed to the specifications of radiologists.

Stern served as director of E-Z-EM from the Company's founding until his passing, and also served as the Company's Chairman of the Board from its founding until December 2004, when he was named Chairman Emeritus. Stern also served as Chief Executive Officer from the Company's founding until 1990, as President and Chief Executive Officer from 1990 to 1994, and again from 1997 to 2000.

At his death, Stern was also a director of AngioDynamics, Inc., which he co-founded in 1988 as a division of E-Z-EM. He served as the Chairman of the Board of AngioDynamics from that company's founding until 2004, when it was spun off to E-Z-EM shareholders. He was also instrumental in the founding and development of Surgical Dynamics, which was sold to U.S. Surgical in 1996.

Stern received a BS in chemical engineering in 1953 and an MS in chemical engineering in 1954, both from MIT. He also served as a Lieutenant in the United States Navy from 1955-1958. He is survived by his wife Linda, his children Rachel and Seth, his son-in-law Peter and his daughter-in-law Trisha, and his grandchildren William, Madeleine, and Alexander.

> *"Stern was a giant in the industry, a true visionary, and a guiding light for all who had the privilege to work with him."*

Warren Earl Stewart (ScD '51) 1924-2006

by R. Byron Bird, W. Harmon Ray, and Edwin N. Lightfoot

Warren Earl Stewart **(ScD '51)**, McFarland-Bascom Professor Emeritus of Chemical and Biological Engineering at the University of Wisconsin, died on March 27, 2006, after a long and distinguished career. Stewart was born in Whitewater, WI, on July 3, 1924, to Earl and Avis Stewart. He received both BS and MS degrees at Wisconsin, in 1945 and 1947, and a ScD in 1951 at MIT. All of his degrees were in chemical engineering. While an undergraduate at Wisconsin, he gained fame as the first student in the history of the College of Engineering to graduate with a straight-A academic record. His MIT experience introduced him to numerical analysis and computational techniques, which proved to be essential at the dawn of the electronic computer age.

During World War II, Stewart enlisted in the U.S. Naval Reserve (1944-1946). He returned to Wisconsin as a Navy engineering trainee under the V-12 Program, and after graduation served as a communications officer on the aircraft carrier USS Midway. In 1947, he was married to Jean Durham Potter, who later was alderman for the city of Madison for 16 years from 1977 to 1993. They had six children and 18 grandchildren.

After five years at the Sinclair Research Laboratories, Stewart joined the faculty of the Department of Chemical Engineering at the University of Wisconsin in 1956, where he taught until 1997. As chairman of the department from 1973 to 1978, he recruited and nurtured several young faculty members who went on to become international leaders in their fields and to become NAE members. He supervised many PhD students and postdoctoral fellows, who today hold responsible positions in universities and industrial research laboratories around the world.

His research publications are indicative of his breadth of interests and knowledge. How many chemical engineers could write significant contributions on such widely varying topics as prediction of vapor pressures, reciprocal variational principles, kinetics of benzene hydrogenation, chemical kinetics and reaction engineering, multicomponent diffusion, orthogonal collocation, measurement of diffusivities, droplet vaporization, kinetic theory of rigid dumbbell suspensions, tokamak reactors, thermal diffusion, catalysis, corrosion, parameter estimation, Bayesian statistics, strategies for process modeling and parameter estimation, viscoelastic fluid dynamics, insulation qualities of animal fur, sensitivity analysis, and distillation column design? Whereas most professors tend to become very specialized, Stewart has been an impressive generalist. When he served as departmental chairman, he was able to discuss with all faculty members the details of their on-going research programs. No other departmental chairman in the last half-century has been able to do that.

Stewart published well over 100 research papers, many containing an impressive amount of detail. He wrote several systematically organized series of reviews of many important transport problems, invariably using his facility in applied mathematics. The first of these series dealt with the boundary-layer theory for momentum, heat, and mass transfer in laminar, multicomponent systems. Then came a series of papers in *AIChE Journal* dealing with forced convection in three-dimensional flows: I (1963); II (1970); III (1983); IV (1988); the second of these is the famous paper dealing with transport across mobile interfaces, coauthored with J. B. Angelo and E. N. Lightfoot. Then in 1974, there was a series of four papers with J. P. Sørensen dealing with computation of forced convection in slow flow through ducts and packed beds, published in *Chemical Engineering Science*.

Among Stewart's most important technical contributions were his development of new mathematical and computational methods for modeling chemical phenomena and chemical processes. His work in this area led to better design and safer operation of chemical processes involving chemical reactions, transport of heat and mass, and the complex flow of fluids. His research results, which have been adopted around the world, increased the fundamental understanding of chemical phenomena and significantly influenced industrial practice.

In addition, there were many publications dealing with the analysis of diffusion experiments, and the collection and correlation of diffusivities for various gaseous and liquid systems. In 1964, he and Richard Prober wrote a paper about the matrix approximations for multicomponent mass transport in *Industrial and Engineering Chemistry Fundamentals*; this work was followed by an article in *AIChE Journal* dealing with multicomponent diffusion in turbulent flow in 1973. An analytical solution of which he was particularly proud was that of the Fourier analysis of energy transport in turbulent tube flow at large Prandtl numbers, which appeared in *AIChE Journal* in 1987. The work on multicomponent diffusion and that on turbulent heat transfer were included in the second edition of *Transport Phenomena*, by R. B. Bird, Warren E. Stewart, and E. N. Lightfoot (2002), §22.9 and §13.6, respectively.

Beyond influencing his own research students, he was an inspiring teacher and valuable consultant for many students and professors in the Chemical Engineering Department. Furthermore, Stewart was a coauthor of the 1958 green paperback *Notes on Transport Phenomena*, which served as a preliminary edition for the 1960 textbook, *Transport Phenomena* (published by John Wiley & Sons in New York). This textbook changed the direction of Chemical Engineering teaching everywhere in the world. It was translated into Spanish, Russian, Italian, Czech, and Chinese. After 64 printings of the first English edition, a second edition was prepared by the same trio of authors. This new edition appeared in 2002 and has been translated into Chinese, Portuguese, and Spanish.

In the preparation of this textbook, Stewart displayed important characteristics that were invaluable: very high standards for writing technical material, a photographic memory of the technical literature, and his insistence that there be no spelling or grammar errors (this last quality earned him the nickname "gimlet eye"). Furthermore he didn't allow any question marks to be missed (he would say "I think we've missed a little 'button-hook' at the end of the penultimate sentence").

At the time of his death, he had almost completed Computer-Aided Modeling of Chemically Reactive Systems (by Warren E. Stewart and Michael Caracotsios), along with accompanying software. This book provides an overview of chemical kinetics and reactor modeling, as well as an extensive description of strategies for parameter estimation based on noisy and incomplete data sets. An interactive software package is included that can perform all the necessary modeling and parameter estimation calculations based on the problem details supplied by the user.

Despite his quiet demeanor and modesty, Stewart received many awards for his research and teaching: Elected Fellow of AIChE (1973); Citation Classic status for Transport Phenomena (see Current Contents, 17 September 1979); Citation Classic status for "Solution of Boundary Value Problems by Orthogonal Collocation" (see Current Contents, 21 September 1981); Alpha Chi Sigma Research Award of AIChE (1981); Benjamin Smith Reynolds Award for Excellence in Teaching, University of Wisconsin College of Engineering (1981); Chemical Engineering Division Lectureship Award, American Society of Engineering Education (1983); Honorary Member of Phi Beta Kappa (1983; McFarland-Bascom Professorship (1983); Computing in Chemical Engineering Award, CAST Division of AIChE (1984); E. V. Murphree Award in Industrial and Engineering Chemistry, American Chemical Society (1989); Byron Bird Award for Outstanding Research Publication, University of Wisconsin College of Engineering (1991); and membership in the National Academy of Engineering (1992). The hallmark of Stewart's career was understated excellence in his work and unfailing kindness to students and colleagues.

He was given honorary membership in Phi Beta Kappa for his exceptional scholarship and his extensive contributions to Chemical Engineering in Mexico and South America. He was a visiting professor at the Universidad Nacional de La Plata in Argentina in 1962, at the Universidad Nacional Tecnológico de Celaya in Mexico in 1983, and at the Universidad Autónoma de México in 1985. At these institutions he lectured in Spanish. For 18 years he was an editorial advisor for the Latin-American Journal of Chemical Engineering and Applied Chemistry. Following that, he held a similar position for Latin-American Applied Research.

Warren Stewart was well known for his sly sense of humor and his ability to produce, instantly, jokes on just about any topic. He loved puns and had a warning sign on his desk given to him by colleagues: "Incorrigible punster — don't incorrige." ▫

Alumni Donors

This honor roll is a special salute to those who have given over $100 for the period July 1, 2004, through June 30, 2006.

Thank you to everyone who has supported us throughout the year!

Every effort has been made to ensure the accuracy of this list.
Please direct corrections to: ***Melanie Miller, Editor***
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Developing the Principles Governing the Adaptive Immune Response Using an Approach at an Intersection of Engineering, the Physical Sciences, and Biology

Professor Arup Chakraborty

Higher organisms, like humans, have an adaptive immune system that enables them to combat pathogens that they have never encountered before. The adaptive immune response is orchestrated by a class of cells called T lymphocytes (T cells). Their importance in maintaining our health is highlighted by the fact that HIV infections compromise the adaptive immune system by infiltrating T cells, which then makes a patient susceptible to a host of opportunistic infections. On the other hand, spurious activation of T cells results in a variety of autoimmune disorders such as multiple sclerosis, diabetes, and arthritis. Thus, understanding how adaptive immunity is regulated is an important fundamental question in biology with far-reaching consequences for the development of intervention protocols that may alleviate human suffering.

In spite of enormous progress, the mechanisms that underlie T cell activation are not understood. This is because it is the result of cooperative dynamic processes that involve many molecular components acting in concert. This inherent cooperativity makes it difficult to intuit underlying mechanisms by observing a few experimental reporters. Recent advances in video microscopy have produced vivid images of the consequences of these cooperative dynamic processes, and have encouraged efforts to confront the challenge of elucidating the pertinent mechanistic foundations of T cell activation, and its mis-regulation. Over the last one hundred years, statistical mechanics has evolved to be a discipline that is focused on understanding cooperative processes, albeit in simpler synthetic systems. A few years ago, Professor Chakraborty's research group was fortunate to have recognized that statistical mechanical methods, along with the principles of reaction engineering, could become powerful complements to genetic, biochemical, and imaging experiments in unraveling the mysteries of T cell activation. They have developed and applied these methods, in close synergy with experimental studies carried out in leading immunology laboratories, to shed light on significant questions relevant to T cell biology [e.g., 1-4]. The primary focus of Professor Chakraborty's research is to build on these successes to develop the principles that underlie how T cells get activated as well as the aberrant regulation of these processes. A hallmark of his work is that, while the computational/theoretical studies carried out in his group are at the cutting edge of engineering and statistical physics, it is also closely synergistic (indeed, collaborative) with experiments in the leading immunology laboratories in the world.

T cell activation involves processes that occur over a wide range of length and time scales (Fig. 1). Events that occur over molecular time and length scales influence events on the scale of the entire cell which, in turn, regulate behavior on the scale of tissues and organs. Interestingly, this is not a one-way street; phenomena that occur on larger scales also influence events on shorter scales. The focus of the Chakraborty group is on unraveling the mechanistic underpinnings of these hierarchically cooperative processes via computational studies that are synergistic with in vitro and in vivo experimentation carried out by their collaborators. To develop this new paradigm in molecular immunology research further, they have recently established the Immune Response Consortium, a major NIH funded effort based at MIT, that brings together physicists, chemists, engineers, and immunologists.

Protein | Cells & Signaling | Tissues & Organs

Figure 1: Multiscale cooperative processes underlying T cell activation. Signaling complexes assemble at the molecular scale upon interaction of T cells (blue) with molecular signatures of pathogen displayed on antigen presenting cells (green). Various signaling complexes in the T cell must act cooperatively on length scales that span the cell. These processes occur as T cells hunt for antigen in tissues.

An example of the kind of questions that Professor Chakraborty's group addresses is provided by work that they do in collaboration with Prof. Mark Davis' laboratory at Stanford University's School of Medicine. T cells recognize the protein component of pathogens. Proteins coded for by the pathogen are spliced in to peptide (p) fragments that can bind to protein products of the major histocompatibility (MHC) gene complex. These pathogen-derived pMHC molecules are displayed on the surface of antigen presenting cells (APC). The T cell receptor (TCR) expressed on T cell membranes can bind these pMHC molecules to initiate signaling processes that can lead to T cell activation. APC surfaces also display a large number of pMHC molecules where the peptide is derived from endogenous proteins ("self"). Recent single molecule imaging experiments carried out in Mark Davis' laboratory demonstrated that T cells can detect as few as 10 molecules of pathogen-derived pMHC molecules in a "sea" of 30,000 endogenous ones [5]. This remarkable sensitivity is not accompanied by frequent spurious triggering (autoimmune responses). How is this remarkable ability to discriminate between "self" and "non-self" regulated by the T cell? The

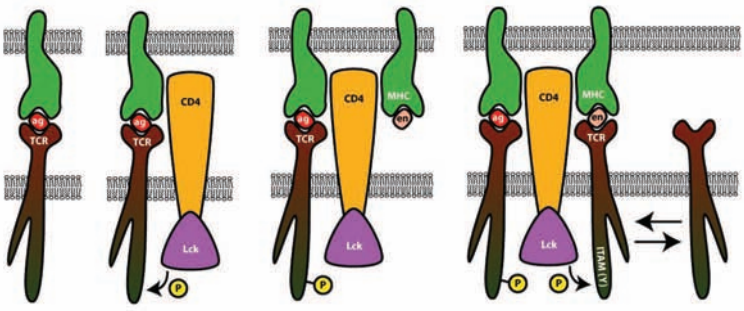

Figure 2: A cooperative mechanism underlying T cell sensitivity to antigen. Antigen-derived (Ag) pMHC bind TCR to nucleate signaling complexes because they are held together for a sufficiently long time to enable the recruitment and binding of the kinase Lck, which phosphorylates TCR to initiate signaling. Some of the multitude of endogenous (En) pMHC can associate with this complex. TCR that bind to such En pMHC can be triggered in spite of the short half-life of this interaction because Lck is already spatially localized in the signaling complex, thereby amplifying signaling from minute amounts of Ag pMHC. In the absence of Ag pMHC, spurious triggering does not occur because En pMHC bind TCR for too short a time to nucleate signaling complexes with Lck.

Chakraborty group has developed and applied sophisticated statistical mechanical approaches [e.g., 2] which, in close synergy with experiments in Professor Davis' laboratory, have begun to elucidate the pertinent mechanisms (Fig. 2). A major finding is that endogenous pMHC molecules play a key role in the ability of T cells to detect minute amounts of antigen by amplifying signaling via a highly cooperative mechanism. This result has broad implications for a host of fundamental questions in immunology.

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Multiscale Analysis of Pharmaceutical Powder Processing

Professor Charles L. Cooney

One of the challenges associated with modern medicine is the consistent manufacture of drug products to assure safe and efficacious delivery each and every time. With 80% of the drug products manufactured as solid dosage forms, this need translates to assurance that each tablet or capsule has the same amount of active drug that is released in the same rate to the patient. From a process engineering perspective, we need to design and control operations at the multi-ton scale that when subdivided into tablets lead to identical aliquots at sub-gram scale. This problem is compounded by the trend towards highly active drugs such that they comprise less the 5% of the mass of a tablet; thus making the challenge of assuring homogeneity at the sub-gram scale even more difficult.

We have addressed this multiscale problem by seeking to understand how the properties of the smallest divisible unit of a pharmaceutical preparation, the particle, influence flow and mixing behavior of powder mixtures. Can one predict large scale process performance from micro-scale powder properties? With such knowledge, one should be able to influence tablet design by manipulation of relevant particle properties. In pursuit of this goal, we developed an on-line, non-invasive method to measure powder mixing dynamics using light induced fluorescence (LIF) of one material in the mixture; commonly, the active pharmaceutical ingredient will fluoresce while the non-active excipients comprising the bulk of the tablet do not. With LIF we measure in real time the mixing kinetics for dry powders as if they were fluids; this provides a performance metric for large scale mixing as seen in figure 3.

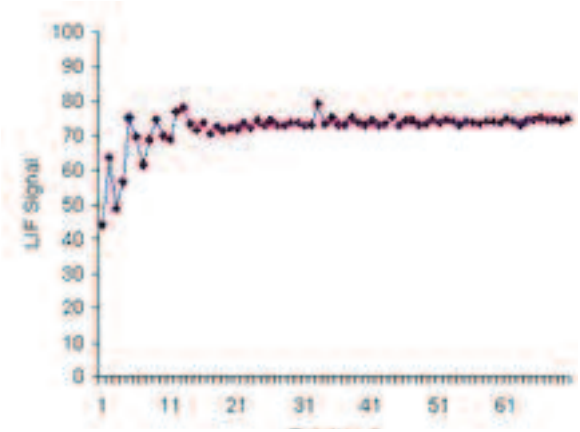

Figure 3. Powder blending kinetics

At the microscale, we identified as critical properties particle size, density, surface roughness (friction), and cohesive interaction. Measurement of size and density was straightforward. The measurement of both interparticle cohesion and friction could be achieved with Atomic Force Microscopy (AFM). We learned that the cohesive force between two particles was obtainable with AFM by attaching one particle to a surface and the second to the cantilever of the AFM (Fig. 4). Multiple measurements on sets of particles gave us the frequency distribution for these forces (Fig. 5). By using the same set up with AFM to drag one particle across another with variable normal load we could also obtain the friction interparticle friction coefficient. The third step in this multiscale approach was to predict flow and mixing performance; to do this we employ

Research Highlights

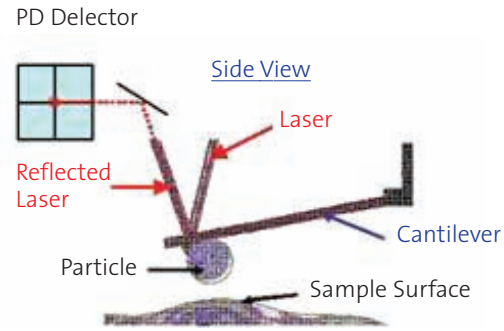

Figure 4: Cohesive force measurement

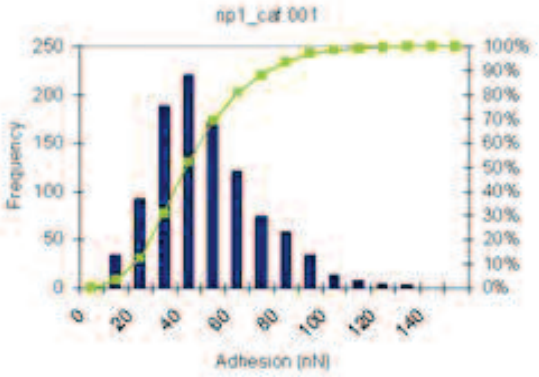

Figure 5: Caffeine particle cohesion

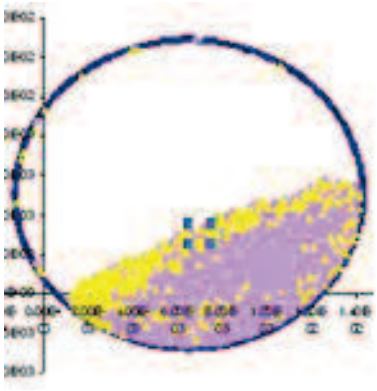

Figure 6: Mixing visualization

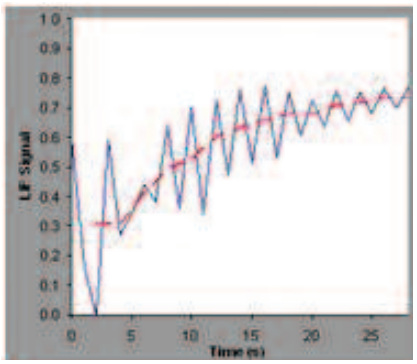

Figure 7: Kinetics simulation

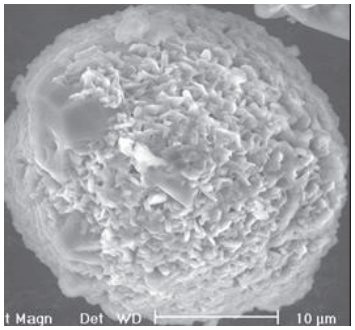

Figure 8: ESEM lactose

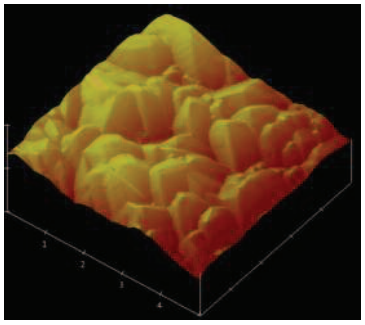

Figure 9: AFM image of lactose

Discrete Element Method (DEM) of simulation that allows us to assign real properties to a set of particles and calculate their dynamic behavior during blending. Although computationally intensive, it uses measured properties to predict performance in a manner that can be compared directly with LIF monitoring in a blender. The simulation is easily visualized (Fig. 6) and sampled (Fig. 7) and leads to estimates of mixing time comparable to experimental observation.

Our current work is to dissect the net cohesion force measured by AFM to understand the component van der Waal's, electrostatic and capillary forces. The complexity of the problem is seen in electron microscopic (Fig. 8) and AFM (Fig. 9) images of the particles and their surface structure. With current methods we have elucidated how particle properties impact the ability to achieve both mixing kinetics and mixture homogeneity. Current work is directed to elucidation of a particle design strategy to facilitate pharmaceutical quality by materials design.

Research on novel and useful surface/thin-film phenomena found in nature

Professor Robert E. Cohen

Professor Robert E. Cohen, in collaboration with colleague Professor Michael F. Rubner of the Department of Materials Science and Engineering, has been directing his attention to novel and useful surface/thin-film phenomena that are found in nature. In one example, their discovery of a successful synthetic route to robust superhydrophobic surfaces led to a patent application, and a communication in NanoLetters that was flagged by the press in a June 7, 2004, *Chemical and Engineering News* feature "Lessons from Lotus Leaves." Quoting *C&E News*: "A surface of micrometer-sized hills and valleys dotted with waxy nanoparticles gives the lotus leaf its superhydrophobic self cleaning properties. Water droplets bead up and roll off the rough surface, taking dirt and debris with them. Using a simple, water-based process, researchers from MIT have created a polyelectrolyte multilayer coating that mimics the leaf's tidy topography [*Nano Lett,* published online May 18, 2005 **http://dx.doi.org/10.1021/nl049463j**]. The group, led by Robert E. Cohen and Michael F. Rubner, first creates micrometer-sized pores in a polyelectrolyte surface (shown in figure 1) via multiple low-pH treatments. They then add nanoscale texture by depositing silica nanoparticles onto the material, followed by a semifluorinated silane coating. The material retains its superhydrophobic character even after being immersed in water for a week. By eliminating the semi-fluorinated silane coating step, the team can make the material superhydrophilic."

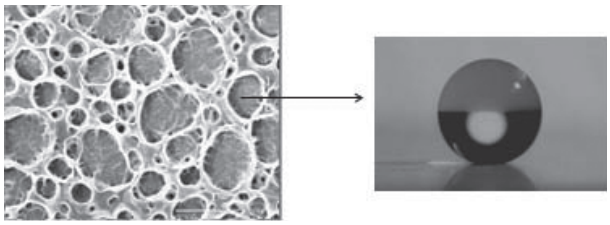

Figure 1

Cohen, Rubner and their postdoctoral associate Dr. Lei Zhai, have been similarly motivated by optical properties of hummingbird wings which demonstrate magnificent changes in color as the angle of observation varies. In this case, spatially controlled variations in porosity in ultra thin films are responsible for the photonic mirror effects. Using the same aqueous-based layering techniques mentioned above, the team has produced lamellar structures that mimic the wing's alternating nanoporous/fully dense ultrastructure (Figure 2.) The tunable Bragg reflectors, based on the step changes in refractive index that result from the porous to dense excursions, were first disclosed in a patent application and then published in the ACS journal, *Macromolecules*, 37, 6113 (2004).

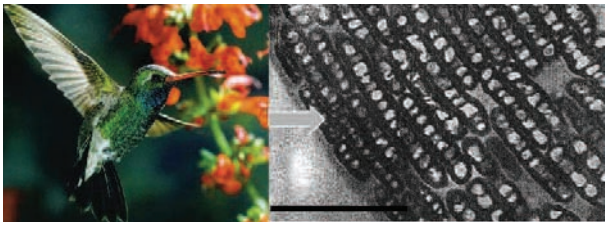

Figure 2

In a further improvement aimed at eliminating unwanted side bands in the reflection spectra of the photonic films, Cohen used his well-known in-situ "nanoreactor chemistry" techniques, Supramolecular Science, 1, 117 (1994), to generate, with nanometer length-scale precision, arrays of high index silver nanoparticles inside the ultrastructure. The challenge, described in a publication in Langmuir, 20, 3304 (2004), was to generate a sinusoidally varying refractive index gradient in the film (known as a Rugate structure) to suppress the side bands. As shown in Figure 3 below, this strategy produced remarkable nanocomposite structures comprised of as many as 1500 polylectrolyte layers with appropriately embedded silver nanoparticles. The locations and magnitudes of the narrow, nearly side-band-free, reflectance peaks depend on the predetermined density of the silver nanoparticles in the high index regions of the designed heterostructure.

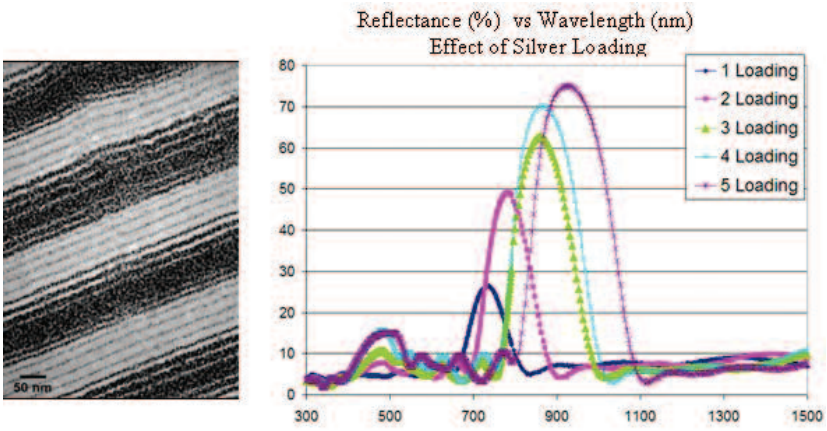

Figure 3

Attention is now focused on two other natural phenomena: Water gathering/channeling properties of the surface of the Namid desert beetle and antireflectivity of moth eyes. The former is based on juxtaposed patchy regions of superhydrophilic and superhydrophobic character on the back of the beetle, a structure that Cohen and Rubner have already reproduced successfully in their laboratories. Tiny droplets of water accumulate on the superhydrophilic regions, grow in size and eventually roll freely along superhydrophobic zones to a pre-determined location; in the beetle's case, the water is

directed to its mouth thereby directly linking this novel surface physics to its survivability in arid circumstances. The moth eye provides inspiration for synthetic antireflection coatings that are again based on combinations of polyelectrolyte multilayers and inorganic nanoparticles. Working with a design team from Rockwell International under DARPA funding, the MIT group is currently addressing the challenge of producing antireflection coatings on flexible, fluid-filled lenses for use in lightweight zoom optical systems for deployment on drone surveillance aircraft.

Molecular Engineering of Stabilizers of Therapeutic Proteins and Antibodies

Bernhardt L. Trout

Proteins (including antibodies) are only marginally stable and degrade by a variety of chemical and physical routes, the most common of which is aggregation. The impacts of aggregation range from the onset of human diseases, such as Alzheimer's, to significant productivity losses in the pharmaceutical industry. Because of the vital role played by proteins in industry and biology in general, significant work has been directed toward understanding aggregation mechanisms. A general solution to this problem would be of great benefit in industrial applications where aggregation is prevalent, such as cell-based and cell-free protein synthesis, protein purification, and protein formulation. Protein formulation is the development of aqueous solutions of very expensive therapeutic proteins that are stable enough to be marketed. In addition to protein formulation, a manufacturing process that is often plagued by aggregation is that of protein refolding. Empirically, it has been found that solution additives such as arginine often deter aggregation and result in a higher yield of properly refolded, active protein.

Before Trout's group began working in this field three years ago, the level of theory was heuristic and driven by phenomenological approaches, which need a large amount of empirical input. Trout and coworkers have developed a molecular modeling approach that allows the computation of free energies of interaction from first principles (no ad hoc fitting parameters) with experimental accuracy. Furthermore, they used this approach to obtain details of the interactions of each chemical group with other groups, thus both generalizing and quantifying the concepts of hydrophobicity and hydrophilicity. Finally, they have used their approach to develop a new concept for the stabilization of proteins. This new concept is based on new molecules, called "neutral crowders," described in more detail below. The "neutral crowder" concept has the potential to be the first new approach to stabilizing proteins in 30 years and to be an enabling technology for new pharmaceutical products.

Neutral crowders deter protein-protein association. Because these additives reduce protein-protein interactions, they address the prevention of aggregation phenomena, which exhibit second, or higher order kinetics, such as aggregation during refolding and some cases of aggregation from the native state. Note that all aggregation events can be made to be second order, if the barrier to protein-protein aggregation can be selectively increased.

The action of neutral crowders is based on a new theory developed in Trout's group about how additives could affect protein association reactions. This idea, called "gap effect theory" (Figure 4), demonstrates that it is possible for an additive to exert a purely kinetic effect on protein association reactions. Specifically, it is possible for a large additive that does not affect the free energy of isolated protein molecules to increase significantly the free energy barrier for association. Such additives are called "neutral crowders," because their interaction is neutral with respect to reactants and products; and they crowd the protein association complex, making it less stable. This effect arises because the large additive is preferentially excluded from the protein-protein encounter complex as seen in Figure 4.

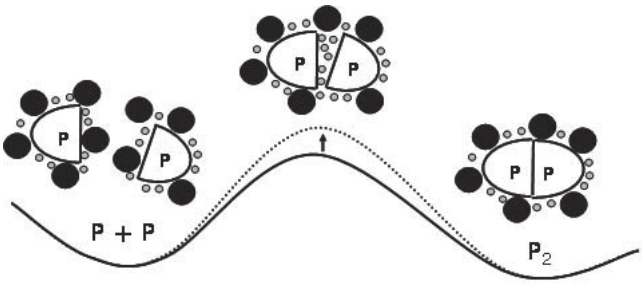

Figure 4: The gap effect. A free energy-reaction coordinate diagram for protein-protein association in a mixed solvent is shown. In the dissociated (P+P) and associated (P2) states, the large additive (black circles) and water (grey circles) can both solvate the protein equally, and there is no thermodynamic effect. At intermediate separations (center), there will be a separation distance where the gap between the protein molecules excludes the large additive for steric reasons, but water can still solvate the gap. This results in a net preferential exclusion of the additive, and a selective free energy increase in the encounter complex. This effect slows protein association reactions exponentially with an increase in the barrier.

Gap effect theory suggests that large solution additives that do not affect the free energy of isolated protein molecules will still slow protein-protein association reactions. Such molecules are rare, because as additive size is increased, the preferential binding coefficient and hence protein transfer free energy falls off as the third power of the additive radius due to an excluded volume effect.

However, Trout's group has discovered one natural molecule whose effects on association reactions are consistent with the assertion that it is a neutral crowder: the amino acid arginine. Specifically, they have shown:

- Arginine decreases the rate of association of globular proteins, as measured by surface plasmon resonance (BIAcore).
- Arginine decreases the rate of association of unfolded and partially-unfolded intermediates in the folding pathway during refolding, as measured by native protein activity and size exclusion HPLC.

The magnitudes of these effects are consistent with their gap effect theory.

As seen in Figure 5, if a neutral crowder larger than arginine can be synthesized, it has the potential to depress protein association rates tremendously. Arginine decreases the rate of association by a factor of three or so, but for an 8 Å additive, the rate of association may be depressed by 2-3 orders of magnitude.

There are a few existing molecules that are putative neutral crowders. One class is dendrimers with the right termination. Another is small molecules which are like arginine, but which have multiple guanidine residues. Trout's group is currently obtaining these molecules and testing their ability to hinder aggregation of real therapeutic proteins, including antibodies.

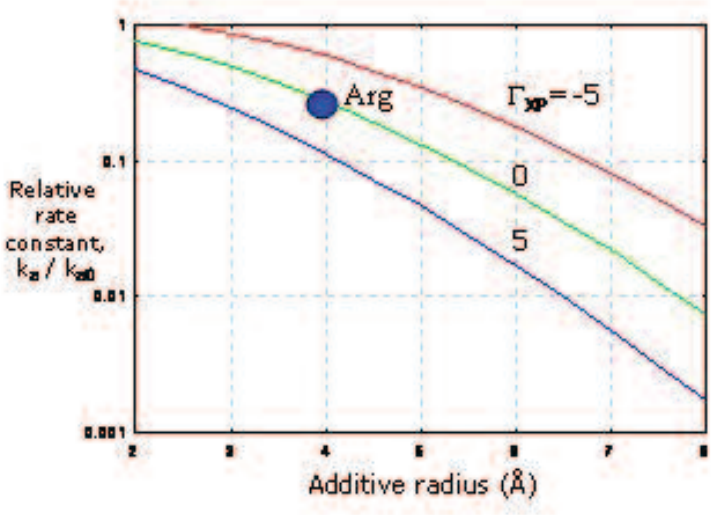

Figure 5: Association rate depression with increasing additive size as predicted by gap effect theory. The relative association rate constant (k_a/k_{aO}), comparing the rate in the presence of an additive to the rate in its absence, is plotted as a function of additive radius and additive-protein preferential binding coefficient. The binding coefficient, XP, is the computed preferential binding. To suppress association, an additive should be large and as attractive to proteins as possible.

GSC-X Activities

By Kevin Brower

Daniel Pregibon and Rocco Ciccolini dress as their favorite reading material at the Halloween TG.

Greetings to all from this year's fearsome group of GSC-Xers. Having recently handed over the reins to another edition of the GSC-X, it seems a better time than most to reflect back on the year that was.

The GSC-X got the year off to a boisterous start during the American Gladiators-themed summer BBQ complete with a one-thousand square foot inflatable obstacle course, jousting pit, and traditional dunk tank. Highlights from the day include the ravenous consumption of a bountiful spread of BBQ foods and Professor Rutledge's overconfident attempt to read a journal article while perched upon the plank of the dunk tank.

The fall semester saw the Welcome, Halloween, and Thanksgiving TGs come and go as usual. However, the unprecedented addition of a *second* October TG truly delighted the Course 10 graduate student body. Word has it that a few first years even escaped the grasps of thermo and transport to come to a TG or two, even if was just to sneak food back to their offices. The fall semester concluded with the Holiday Party. The comedy of this year's 1st and nth year skits could only equaled by the audience's ennui throughout the faculty skit (It's okay faculty, we're just kidding!).

Graduate students face off at the Course 10 Summer BBQ.

The spring semester began with the reminder that graduate school is not always fun and games as the GSC-X played its part in assisting the 1st years navigate their way through the qualifying exams. The TGs for this semester covered a broad range of themes from the Winter Olympics with hockey in the halls of 66 to American Idol with inspired karaoke performances. Before the final Cinco de Mayo TG, a specious referendum rife with suspicious voting practices brought Dance Dance Revolution out from the ashes for an appearance at the last prospective student visit weekend. The department readies itself for the (sort of) Annual ChemE Golf Scramble to be held at Pembroke Country Club complete with an appearance by Professor Armstrong.

The ChemE IM sports teams completed a year of remarkable performance on the fields and courts showing little mercy in competition against undergrads and graduate students alike. A championship was won in Unihoc A league in a hardly fought match against Alpha Tau Omega. Runner-up performances were also achieved in A league Octathon, A league basketball, and B+ league volleyball.

Best wishes,
Your GSC-X (alumnae)

Melanie Miller, Editor
Department of Chemical Engineering

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