

Chemical Engineering at . . .

Iowa State University

CHRIS NEARY,
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AND GEORGE BURNET

In many ways, Iowa State chemical engineering epitomizes the land-grant philosophy its university lives by—Iowa State University was the nation's first land-grant university. It is the birthplace of the first digital computer and is one of the few universities to host a Department of Energy national laboratory, Ames Laboratory, on its campus. Iowa State ranks second among universities in R&D 100 awards, given by *R&D* magazine for top technologies. The College of Engineering is the 10th largest in the nation. It is home to many interdisciplinary research centers of excellence including a National Science Foundation Engineering Research Center (NSF-ERC) focused on Biorenewable Chemicals. This research center, commonly referred to as CBiRC, is led by Iowa State chemical engineering faculty members.

This year, the Department of Chemical and Biological Engineering at Iowa State University, currently the ninth largest in the nation, celebrates its centennial—2013 marks 100 years of education and research excellence in chemical and biological engineering at Iowa State University. This is a key milestone for the department as it looks forward to



Sweeney Hall is home to the Department of Chemical and Biological Engineering at Iowa State University.

continuing the long tradition of excellence and building on its successes for the next 100 years.

CENTENNIAL HISTORY*

Chemical engineering courses at Iowa State were originally offered in the Department of Mining Engineering, Ceramics, and Chemical Engineering in 1913. Dr. **O.R. Sweeney** led the Iowa State chemical engineering program and began pioneering work on utilization of agricultural wastes. Sweeney became “Iowa’s Edison” as he served on national panels with the likes of General Motors Chairman **Alfred Sloan**, FBI Director **J. Edgar Hoover**, and Canadian Prime Minister **W.L. McKenzie**. Today, Iowa is home to a wealth of agricultural raw materials that would otherwise be wasted. With the

* Some parts of this text are summarized from “100 Years of Chemical and Biological Engineering at Iowa State University,” by George Burnet and Steve Sullivan, set to be published in summer 2013. All copyrights reserved.

field of biorenewables experiencing resurgence, it is worth looking at our departmental history for some of the earliest successes that have shaped this field. For example, research on furfural from agricultural byproducts took place at Iowa State from the 1920s to 1940s. In the book, *Creation of the Modern Land-Grant University: Chemical Engineering, Agricultural By-Products and the Reconceptualization of Iowa State College*, **Alan Marcus** notes that “the destructive distillation of corncobs liberated substantial quantities of (furfural). Ames engineers not only refined furfural production techniques and designed the blueprints for commercial facilities, but also set about to determine furfural’s potential industrial uses.”

In 1936, the Engineers’ Council for Professional Development (ECPD, now ABET) first accredited the Iowa State chemical engineering program. The American Institute of Chemical Engineers (AIChE), a founding society of ECPD, recognized the Iowa State University chemical engineering program in 1925. Because Iowa State was one of the first schools to be recognized by AIChE, many schools around the country patterned their courses after Iowa State. In fact, the Iowa State program was the first to offer chemical engineering plant design as a course. In 1926, **Juanito Mina** was the first female graduate of the Iowa State chemical engineering program. One year later, the department moved into its own building complete with a large unit operations laboratory,

classrooms, offices, and research labs. The U.S. Department of Agriculture built its By-Products Laboratory west of the Chemical Engineering Building in 1935, further strengthening work on the utilization of agricultural wastes. In 1964, Sweeney received the ultimate honor (six years after his passing) when a second chemical engineering building was constructed and named Sweeney Hall. The new three-floor building added dozens of faculty and graduate student offices and new spaces for research. By the time Sweeney stepped down as department head in 1947, Iowa State’s chemical engineering program was one of the largest and most highly respected in the United States.

In 1947, chemical engineering research was significantly enhanced with the creation on campus of the Ames Laboratory, an interdisciplinary research laboratory of the Atomic Energy Commission (now the U.S. Department of Energy). The Ames Laboratory became a “clearinghouse for nuclear research on campus, a public resource for atomic energy consultation, a liaison between Iowa State, the Argonne National Laboratory, and its associated 25 Midwestern universities, a mecca for graduate students, and an administrative hub for processing federal and private funds as they become available,” according to **Joanna Abel Goodman’s** *National Science in the Nation’s Heartland: The Ames Laboratory and Iowa State University, 1942-1965*. Through a chemical



Chemical engineering students build a “Products of Corn” float for 1937 VEISHEA, the country’s longest student-run festival. Items displayed on this float include syrup, starch, rayon, and wallboard—all made in Iowa State labs from corn. This demonstrated various ways chemical engineering was commercialized in the 1930s.

engineering division at the Ames Laboratory, chemical engineering faculty and graduate students were very involved in the development of processes for the recovery of thorium, rare earth minerals, and uranium from monazite sands, all high-priority needs at that time.

In 1957, the department name changed from the Department of Chemical and Mining Engineering to simply the Department of Chemical Engineering. In 1959, the Iowa State College of Agriculture and Mechanic Arts was renamed Iowa State University of Science and Technology.

From 1961 to 1978, **George Burnet** led Iowa State chemical engineering with engineering education as the significant focus. Burnet held many positions nationally including as president of American Society for Engineering Education (ASEE); national president of Omega Chi Epsilon; U.S. representative to the United Nations Committee on Education and Training; member of the NSF Commission on Precollege Education in Mathematics, Science, and Technology; and many more.

Ray Fahien, a faculty member in the department, also echoed Burnet's passion for engineering education. From 1967 to 1995, he served as the editor of *Chemical Engineering Education*. The journal created an award after him, which honors an educator who has shown evidence of vision and contribution to chemical engineering education.

In 1968, Iowa State chemical engineering's first female doctoral candidate, **Idelle Peterson**, graduated.

Maurice Larson became department chair of chemical engineering in 1978. Larson and his crystallization work put Iowa State University on the world map. In a 1988 letter, Professor **John Garside** from The University of Manchester said, "(Iowa State's) work on crystallization has enabled crystallizer design methods to be put on a rational, quantitative basis.... Virtually all chemical engineering crystallization research groups throughout the world now base their developments on these methods." Professor **Richard Seagrave** became department chair after Larson stepped down in 1983. Seagrave picked up on Larson's vision to expand Sweeney Hall facilities to accommodate the new research areas such as biotechnology. Larson's vision for expanded facilities, and the continued work of Seagrave and **Terry King**, who became chair in 1990, culminated in the dedication of the Sweeney Hall addition in 1994. The \$8 million addition expanded Sweeney Hall by 35,000 square feet. In 2005, the department changed from the Department of Chemical Engineering to the Department of Chemical and Biological Engineering to better reflect the bio-based research and teaching under way.

L.K. Doraiswamy joined Iowa State faculty as Glenn Murphy Visiting Professor in Engineering in 1989. At Iowa State he helped create a research program in catalysis and reaction engineering. In 1998, Iowa State and the National Chemical Laboratory in India established the L.K. Doraiswamy Honor

Lectureship, a dual-lecture series where a distinguished leader in chemical engineering lectures at both Iowa State in Ames, Iowa, and at NCL in Pune, India. Among the highest honors Doraiswamy received was election to the National Academy of Engineering in 2010. Doraiswamy passed away in 2012.

Professor **Charles "Chuck" Glatz** was chair of chemical engineering from 1997 to 2005. During this time the department pursued further interests in biological engineering, and several faculty were hired, mainly at the associate and full professor levels. These included **Brent Shanks**, **Jackie Shanks**, **Rodney Fox**, **Andrew Hillier**, and Vlasta Klima Balloun Professor **Balaji Narasimhan**. In 1999, former chair Seagrave served as interim provost of Iowa State University, and later as interim president of the university from 2000 to 2001. Seagrave stepped into the national curriculum spotlight as chairman of ABET from 1996 to 1997, then as ABET president from 2005 to 2006.

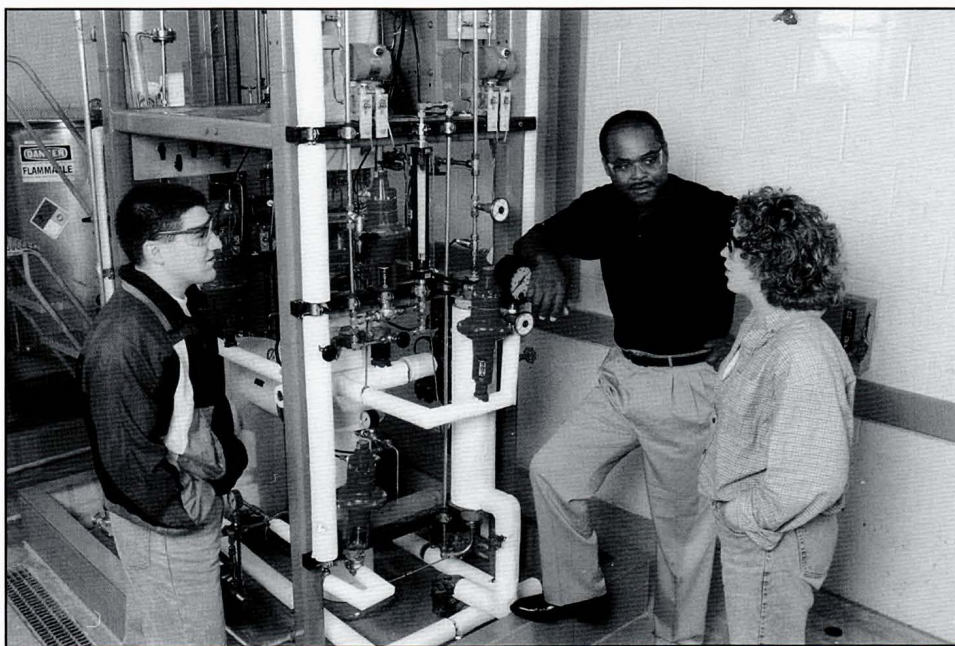
Professor **James Hill** became chair of the department in July 2005. For the next four years, the Iowa State chemical engineering program expanded research in biological and biomedical areas. Six professors joined the faculty during this time. In 2007, ConocoPhillips established an eight-year, \$22.5 million biofuels research program to develop technologies that produce biorenewable fuels, led by Professor **Robert Brown**.

In 2010, the biorenewables faculty and work found a new home at the Biorenewables Research Laboratory, built directly west of Sweeney Hall. The \$32 million Phase I of Iowa State's \$107 million Biorenewables Complex serves as a "front door" to the university's diverse and broad-reaching programs in biorenewables.

In 2009, Professor and Stanley Chair in Interdisciplinary Engineering **Surya Mallapragada**—an Iowa State faculty member since 1996—was named the first female chair of the Department of Chemical and Biological Engineering. Mallapragada's research in biomaterials and bioinspired materials has led to several awards including a TR100 award. Under her leadership, the CBE department has attracted consecutive record enrollment, consecutive record department research expenditures, and record diversity within the student population. To keep up with this rapid growth, the department renovated 20 laboratories in Sweeney Hall through a \$1.75 million competitive grant from the National Science Foundation to grow research in biomedical engineering and nanomaterials. Several teaching spaces have also been renovated through funding from alumni as well as the Carver Charitable Trust.

FACULTY

The department currently has 20 tenure-track/tenured faculty members who are engaged in the research and educational mission of the department. Included among the faculty are four Iowa State B.S. chemical engineering graduates: Assistant Professor **Eric Cochran** (B.S.ChE '98; Ph.D., University



Prof. Derrick Rollins works with students in the undergraduate teaching labs.

of Minnesota), Assistant Professor **Ian Schneider** (B.S.ChE '00; Ph.D., North Carolina State University), Mike and Jean Steffenson Professor **Brent Shanks** (B.S.ChE '83; Ph.D., California Institute of Technology) and Manley Hoppe Professor **Jacqueline Shanks** (B.S.ChE '83; Ph.D., California Institute of Technology).

Current faculty of the Iowa State CBE department have garnered more than 35 national honors and awards, including NSF CAREER Awards (Cochran, Mallapragada, and Hillier), NSF Young Investigator Awards (**Rodney Fox** and Jacqueline Shanks), and several spots on national research committees and "top" lists. Such lists include MIT Technology Review's Top 100 Young Innovators (Mallapragada and Narasimhan) and Biofuels Digest's Top 100 People in Bioenergy (**Robert Brown**). The department has five professors with the Iowa State College of Engineering's highest faculty honor, Anson Marston Distinguished Professor: Brown, Fox, **Peter Reilly**, Burnet (emeritus), and Seagrave (emeritus). Three faculty members have the University Professor honor: **Charles Glatz**, **James Hill**, and **Thomas Wheelock** (emeritus).

The first female chemical engineering faculty member at Iowa State, **Carole Heath**, was hired in 1993. Today the Iowa State chemical and biological engineering department has one of the country's highest percentages of female tenured/tenure-track faculty. Since Heath, the department has hired eight tenured and three non-tenured female faculty members; today, the proportion is 42 percent female.

Professor **Derrick Rollins** was hired in 1990 as Iowa State chemical engineering's first African-American faculty member. He founded several Iowa State programs for recruitment and retention of underrepresented minority students. His pas-

sion for student success has been recognized nationally by several awards, including the American Association for the Advancement of Science Mentor Award and Tau Beta Pi McDonald Mentor Award.

In August 2007, Narasimhan was named associate dean for Research and Economic Development in the College of Engineering. Among many other successes in this role, Narasimhan has overseen development of the interdisciplinary Dean's Research Initiatives, which are designed to lead to the creation of large center-scale grants.

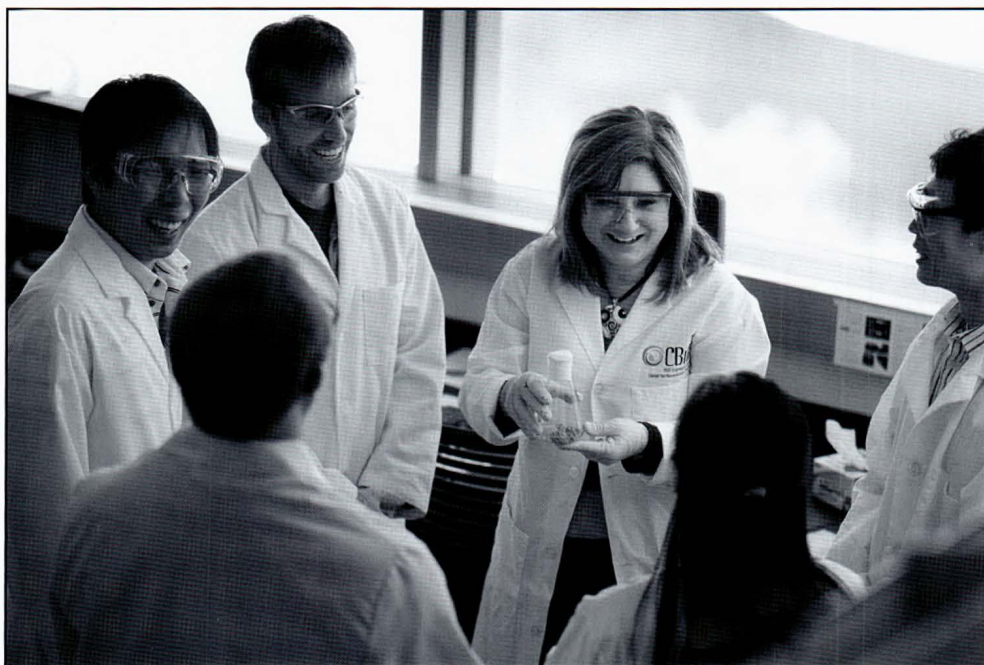
Iowa State biorenewables research received a major boost in 2008 with the creation of the National Science Foundation Engineering Center for Biorenewable Chemicals (CBiRC). NSF contributed \$18.5 million for the first five years of development. Headed by Brent Shanks, CBiRC is Iowa State's first NSF Engineering Research Center and serves to transform the chemical industry into a renewable resource-based industry. In 2012, CBiRC was awarded an additional \$12 million, three-year, NSF grant to continue research and educational activities. Professors Jacqueline Shanks (who also serves as a Thrust Leader in CBiRC), **Laura Jarboe**, Rollins, and Reilly have contributed to the development of CBiRC research and education. Two new departmental hires, **Jean-Philippe Tessonier** and **Zengyi Shao**, are also associated with CBiRC.

Chemical engineering facilities at Iowa State continue to meet the department's leading research and teaching demands. The W.M. Keck Laboratory for High Throughput Atom-Scale Analysis opened in Sweeney Hall in 2007. The 1,600-square-foot space houses leading combinatorial science and atom-scale materials research. A state-of-the-art local electrode atom probe microscope, along with complementary instrumentation, provides the most advanced analysis to date of compositional mapping of materials. Professors Hillier and Narasimhan from CBE led the development of the Keck Laboratory.

UNDERGRADUATE PROGRAM

Over the past 100 years, Iowa State's chemical engineering curriculum has transformed along with the many advancements and diversifications that chemical engineering industries have experienced. Today students can take

Prof. Jacqueline Shanks, the microbial metabolic engineering thrust leader for CBiRC, is pictured here with current students and research staff.



either the general chemical engineering track or biological engineering track. As juniors, undergraduates enroll in a CHE 325 (chemical engineering laboratory I) / ENGL 314 (technical communication) hybrid course that teaches students both how to operate a laboratory and how to develop communication materials that accompany chemical engineering practices. The program also provides a freshmen learning community, which introduces students to the chemical engineering profession, and provides career planning and academic course support. Undergraduates learn in a state-of-the-art two-story unit operations laboratory, named the Herbert L. Stiles Teaching Laboratory after 1929 alumnus **Herbert Stiles**.

Enriching undergraduate experiences extend beyond the Ames, Iowa, campus. In summer 2001, Reilly helped start the International Summer Course in Chemical Engineering, held every summer at the University of Oviedo, Spain. Select undergraduate students participate in an intense, five-week unit operations laboratory course. Iowa State partners in the course with the University of Wisconsin-Madison and the University of Oviedo. Professor Emeritus **Ken Jolls** has coordinated the program since 2002. Students also take advantage of summer, semester, and mini-term internships and co-op experiences at companies in Iowa and throughout the United States. Since its beginning, the Iowa State chemical engineering program has awarded more than 4,700 baccalaureate degrees. More than 250 companies attract interns at the Engineering Career Fair every semester at Iowa State University—site of one of the country's largest collegiate career fairs in engineering—leading to very high placement rates (90%+) for graduates of the college.

In 2006, Iowa State first received NSF funding for the Biological Materials and Processes Research Experience for Undergraduates (BioMaP REU). Every summer since, a dozen or so undergraduate students from around the United States have been matched with Iowa State CBE faculty to conduct 11 weeks of research and present their work at a public symposium on campus.

In addition to coursework and research, Iowa State chemical engineering faculty members have contributed to major literature in the field. Doraiswamy published six top chemical reaction engineering books: *Chemical Reaction Engineering: Beyond the Fundamentals* (2013); *Organic Synthesis Engineering* (2001); *Catalytic Reactions and Reactors* (1991); *Analysis of Chemically Reacting Systems: A Stochastic Approach* (1987); *Across Millenia: Some Thoughts on Ancient and Contemporary Science and Engineering* (1987); and *Heterogeneous Reactions: Analysis, Examples and Reactor Design* (1984). Brown has published three books contributing to biofuels and biorenewable resources: *Why Are We Producing Biofuels?* (2012); *Thermochemical Processing of Biomass: Conversion into Fuels, Chemicals, and Power* (2011); and *Biorenewable Resources: Engineering New Products from Agriculture* (2003). Fox published three books on computational fluid dynamics: *Computational Models for Polydisperse Particulate and Multiphase Systems* (2013); *Multiphase Reacting Flows: Modeling and Simulation* (2007); and *Computational Models for Turbulent Reacting Flows* (2003). Mallapragada and Narasimhan have co-published three books: *Combinatorial Materials Science* (2007); *Handbook of Biodegradable Polymers and Their Applications* (2006); and *Biomaterials for Drug Delivery and Tissue Engineering* (2001). These and other current Iowa State chemical engineering faculty members have served on many journal editorial boards: *AIChE Journal*, *Industrial & Engineering Chemistry Research*, *International Journal of Multiphase Flow*, *Annual Review of Fluid Mechanics*, *The Electrochemical Society's INTERFACE*, *Fluid Dynamics Research*, *Journal of Nanoparticle Research*, *ISRN Nanotechnology*, *Biotechnology Progress*, *Metabolic Engineering*,

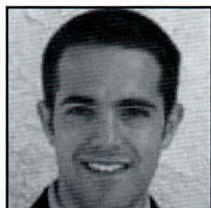
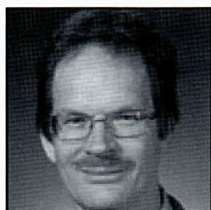
FACULTY GALLERY (In alphabetical order with Ph.D. institution and research area)

Kaitlin Bratlie, University of California-Berkeley. *Biomaterials, tissue engineering, imaging*



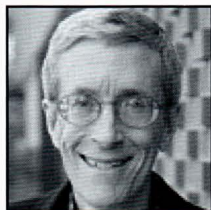
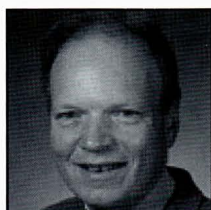
Rebecca Cademartiri, University of Potsdam. *Interactions of biological entities with materials*

Eric Cochran, University of Minnesota-Twin Cities. *Self-assembled polymers*



Rodney Fox, Kansas State University. *Computational fluid dynamics, reaction engineering*

Charles Glatz, University of Wisconsin-Madison. *Bioprocessing, bioseparations*



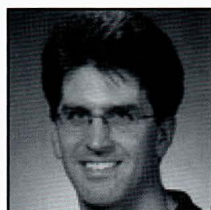
Kurt Hebert, University of Illinois at Urbana-Champaign. *Corrosion, electrochemical engineering*

Jennifer Heinen, University of Delaware. *Mechanism and kinetics of controlled polymerizations in heterogeneous media*



James Hill, University of Washington. *Turbulence, computational fluid dynamics*

Andrew Hillier, University of Minnesota. *Interfacial engineering, electrochemistry*



Laura Jarboe, University of California Los Angeles. *Bio-renewables production by metabolic engineering*



Monica Lamm, North Carolina State University. *Molecular simulation of advanced materials*

Stephanie Loveland, Iowa State University. *Senior lecturer*



Surya Mallapragada, Purdue University. (Department Chair) *Tissue engineering, gene delivery*

Balaji Narasimhan, Purdue University. *associate dean for research for College of Engineering; Biomaterials, drug and vaccine delivery*



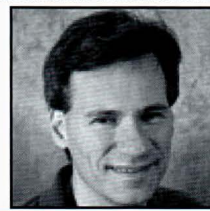
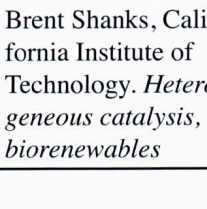
Peter Reilly, University of Pennsylvania. *Molecular mechanics, molecular dynamics, quantum mechanics*

Derrick Rollins, The Ohio State University. *Statistical process control*



Ian Schneider, North Carolina State University. *Cell migration, mechanotransduction*

Brent Shanks, California Institute of Technology. *Heterogeneous catalysis, biorenewables*



Jacqueline Shanks, California Institute of Technology. *Metabolic engineering, plant biotechnology*

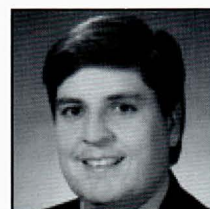


Zengyi Shao, University of Illinois at Urbana-Champaign. *Biorenewables production by metabolic engineering*



Cory Stiehl, University of Massachusetts. *Senior lecturer*

Jean-Philippe Tessonier, Universite de Strasbourg. *Heterogeneous catalysis, biorenewables*



R. Dennis Vigil, University of Michigan. *Transport phenomena, reaction engineering in multiphase systems*

Qun Wang, University of Kansas. *Drug delivery, nanotechnology, biomaterials and stem cells*



Current Opinion in Biotechnology, Electrochemical Society, Biotechnology Letters, Starch, ASME Journal of Nanotechnology in Engineering and Medicine, and ASME Journal of Fluids Engineering.

Several alumni from the department have had notable and distinguished careers and received national/international recognition. Iowa State University B.S. graduates such as **Allen Jacobson** (retired CEO of 3M), **James Katzer** (retired from Exxon), **Paul Willhite** (University of Kansas), **Jerry Schnoor** (University of Iowa), and **Lanny Robbins** (retired from Dow Chemical) have been elected to the National Academy of Engineering. Several alumni with undergraduate degrees from Iowa State University have established successful careers in academia: Alumnus **Tim Anderson** is currently dean of Engineering at the University of Massachusetts; other successful alumni in academia include **Mark Saltzman** at Yale and **Edward McGinn** at the University of Notre Dame.

Distinguished recognitions have come to recent graduates as well. For instance, in 2010, chemical engineering junior **Meredith Gibson** was a guest speaker (the only college student speaker) at the *Fortune* magazine Most Powerful Women summit, held in Washington, D.C. There she shared her Iowa State engineering experiences and involvement with the National Math and Science Young Leaders Program. Gibson graduated with a Bachelor's in chemical engineering in December 2012.

On campus, undergraduate students are very active in chapters of AIChE, Omega Chi Epsilon (chemical engineering honor society), and the National Organization for the Professional Advancement of Black Chemists and Chemical Engineers. In 2010, the AIChE Iowa State student chapter hosted the Mid-America AIChE Student Regional Conference.

GRADUATE PROGRAM

Iowa State offers the Doctor of Philosophy (Ph.D.), Master of Science (M.S.) and Master of Engineering (M.Engr.) degrees in chemical engineering. While Ph.D. and M.S. require a thesis, M.Engr. requires only coursework. M.S. students take an average of two years to graduate, while Ph.D. candidates complete their degrees in 4.5 years, on average. The Iowa State Chemical Engineering Graduate Student Organization (CEGSO) provides a venue for all Iowa State ChE graduate students for special professional development opportunities as well as for volunteering and social activities.

Graduate students become heavily involved in research endeavors in chemical engineering concepts and technol-

ogy used in today's and tomorrow's energy, sustainability, and health industries. Research areas include advanced and nanostructured materials, biorenewables, catalysis and reaction engineering, computational fluid dynamics, health care technology and biomedical engineering, and renewable energy. Biorenewables research is quite popular given Iowa's abundance of biomass as a biorenewables resource. Doctoral graduate **Catie Brewer** (2012) received the 2011 George Washington Carver Award Scholarship Prize for Outstanding Student Achievement in Biorenewables at the World Congress on Industrial Biotechnology & Bioprocessing. Substantial funding has recently been attributed to health care technology and biomedical engineering, particularly in nanovaccine gene delivery and neuroregenerative strategies. Research has been published in high-impact journals such as *Nature Materials* and *Nature*. Since the Iowa State program was founded, 624 Master's degrees and 450 doctoral degrees have been awarded.

Graduate alumni have established successful careers. Recent alumni in academia include **Ganesh Sriram** at the University of Maryland; **Matthew Kipper** at Colorado State University; **Russell Gorga** at North Carolina State University; **Erin Jablonski** and **Brandon Vogel** at Bucknell; and **Venkat Raman** at University of Texas at Austin, among others. **Umit Ozkan**, now a distinguished professor at The Ohio State University, has received many national honors and awards for her teaching and research in heterogeneous catalysis. **Deniz Uner** is the professor and chair of chemical engineering at Middle East Technical University in Ankara, Turkey, and recently co-authored a book with the late Doraiswamy called *Chemical Reaction Engineering: Beyond the Fundamentals* (2013). Our alumni advance their Iowa State chemical engineering research through such academic, industrial, and entrepreneurial endeavors.

SUMMARY

The first century of Iowa State chemical engineering research and education excellence culminates in 2013. The department is proud of the academic, research, and professional networks it identifies with, and will continue to serve as a premier resource for chemical engineering teaching and development. Teaching and research facilities will expand to meet the demands of chemical engineering excellence. Faculty and students will continue to push the frontiers of interdisciplinary research to improve the theory and practice of chemical engineering. In 2013 Iowa State chemical and biological engineering starts an exciting new chapter—its second century. □