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THE EBInsider

EBI FALL SEMINAR SERIES BEGINS IN OCTOBER IN BERKELEY

The new academic year's first scientific seminars sponsored by the EBI will begin on Oct. 6 with a presentation by Berkeley Lab's Terry Hazen, principal investigator of the EBI program on Microbially Enhanced Hydrocarbon Recovery (MEHR).

Hazen's talk will be followed by seminars on Oct. 20 (Susan Leschine of the University of Massachusetts-Amherst), Nov. 3 (Michael Gould of Texas A&M), and Dec. 15 (John Coates of UC Berkeley). Other speakers will be added during the year; all talks take place from 4 to 5 p.m. in Room 116 Calvin Laboratory in Berkeley. They are open to all EBI faculty, staff, researchers, and students.

Hazen heads a three-campus effort studying ways to increase the amount of oil that can be extracted from existing wells by using environmentally friendly microbes. They are also investigating methods of *in situ* biorefining to improve life cycle costs and reduce environmental impacts. He is senior scientist in the Earth Sciences Division at Lawrence Berkeley National Laboratory.

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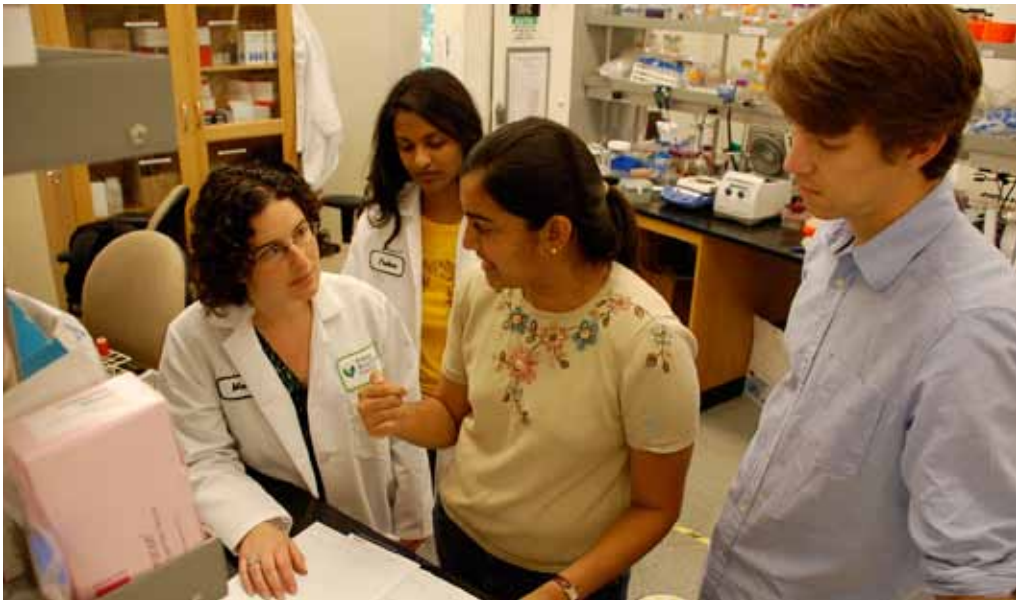

Berkeley Lab Manager Mara Bryan (left) listens to data reported by undergraduate researcher Deepti Purjare as graduate students Padma Gunda (rear) and Jon Galazka look on.

LAB MANAGERS: KEEPING THINGS IN ORDER AT THE EBI

Are the research instruments acting funny? Is there clutter around the bench area? How do researchers reserve time on an instrument? Did someone forget to wear safety goggles? Who's supervising the lab assistants when washing the glassware, making media, or organizing supplies? In Berkeley, contact Mara Bryan. In Illinois, contact Jing Dong.

They are lab managers, who need to know how to order equipment and supplies for principal investigators; install, troubleshoot and train researchers on using scientific instruments; understand all the environmental and safety policies as they pertain to research work areas; answer questions on a wide variety of research and administrative topics; and keep things organized and running smoothly despite the diversity of disciplines, tasks and individuals. "Our role," says Berkeley's Bryan, "is to help all of the researchers do what is necessary in order to accomplish their research. And that's really gratifying."

She should know; she's been EBI lab manager since May of 2008, setting up the workspaces and the systems necessary to support the bench investigations of more than 60 postdocs, graduate and undergraduate students serving a dozen principal investigators. Her counterpart at Illinois, Dong, just took over from founding EBI lab manager Rachel Shekar at the Institute of Genomic Biology and is pursuing her learning curve.

"What happened yesterday," Dong recalled after just one week on the job, "was

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INSIDE THE INSIDER

DEPUTY CHANGES MIND, TO REMAIN WITH THE EBI AND ILLINOIS

To the great relief of everyone associated with the Energy Biosciences Institute, co-founder and Deputy Director Steve Long has rescinded his announced departure and has committed to remain with the University of Illinois and the EBI.

In early August, Long reported that he had accepted a position as Associate Director at Brookhaven National Laboratory in New York, to oversee the Environmental and Life Sciences Departments and also lead the Laboratory's initiative on assessing and seeking global climate change solutions. But after much soul searching, Long decided to commit to staying with Illinois and the EBI.

"My mission since coming to Illinois has been to search for global change solutions that can make a real difference and solutions that can be realized," he said. "I had to conclude that the EBI, coupled with other major projects that have emerged at Illinois outside EBI, would be hard to better. The team of people, both academics and professional staff, that now constitute the EBI have made it the most exciting, creative, positive and fun research environment that I have experienced in a long career. In the end, quite simply I could not leave that behind."

Long, who has a two-decade history of research collaboration with Brookhaven, will now likely act in an advisory role as the Laboratory continues to strengthen its own strong global change solution programs. A number of these involve collaborations with Illinois. "While I regret my premature announcement, I now realize staying was the right decision for me," he added."I am happy to be able to now give the EBI and the University of Illinois my full attention again.

"The EBI has been a great success," he said, referencing the July retreat in Illinois as a milestone. "It is delivering world-class research, and I am optimistic that it will solve a defined and major societal problem within a decadal time frame. Equally, it is defining a new approach to academia-industry interactions in addressing issues of concern to society as a whole."

Long was one of the three co-PI's who developed the original proposal for the EBI to BP and one of the key executives who developed the Institute when Berkeley, with Lawrence Berkeley National Lab and Illinois, gained the award in 2007. He is Professor of Crop Sciences and Plant Biology, and is also Chief and Founding Editor of the leading environmental sciences journal, "Global Change Biology."

YOUNG BP STAFFER RECEIVES 'GREEN CHEMISTRY' HONOR

One of the newest BP team members to join the EBI arrived as a recent 2009 winner of the American Chemical Society's Kenneth G. Hancock Memorial Award in Green Chemistry. Joseph Binder, who was a graduate student at the University of Wisconsin-Madison when the selection was made, was honored for his work in "Simple Chemical Transformation of Lignocellulosic Biomass and Olefin Metathesis in Aqueous Solvents."

The Hancock award is given annually by the ACS to honor outstanding student contributions to furthering the goals of green chemistry through research or education.

The description on his citation follows:

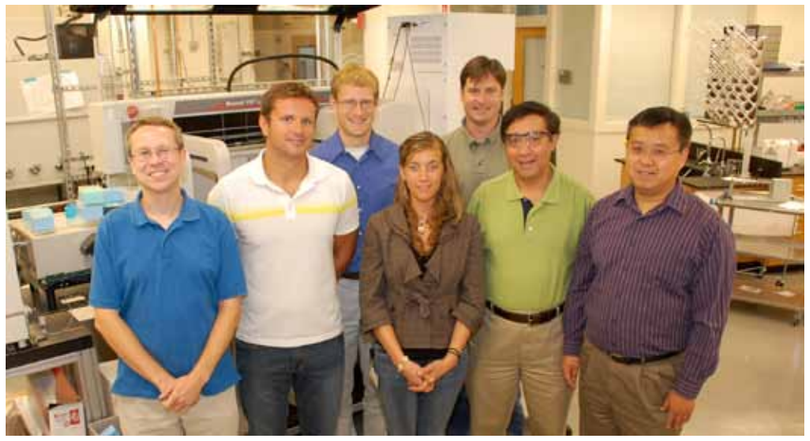
"Most renewable fuels and chemicals are currently made from edible biomass, such as corn, sugarcane, or vegetable oil. But there isn't enough edible biomass available to produce a significant amount of renewable fuels; plus, it competes with the need to feed people and animals. This research has identified a potentially efficient and economical method to transform inedible biomass into renewable products.

"Joseph Binder was selected for his research on transforming biomass into valuable chemicals and fuels, and on olefin metathesis reactions using less hazardous, aqueous solvent conditions for new applications including biomolecule modification.

"In the first system, Joseph has developed mild conditions to convert lignocellulosic biomass into sugars and into 5-hydroxymethylfurfural (HMF), a bio-based platform chemical that can be used to derive many useful chemical products from renewable, non-petroleum resources. His conditions consist of water, acid, and ionic liquids to dissolve and hydrolyze the typically insoluble lignocellulose, plus a catalyst for conversion of the sugars into HMF.

"In the second project, Joseph developed new olefin metathesis catalysts for aqueous reactions, enabling efficient construction of pharmaceuticals, crop protectants, and other chemical products. His unique approach combines solubilizing and stability-enhancing ligands on the metathesis catalysts. Joseph's developments have already opened up the field of greener metathesis to new applications including biomaterials such as proteins."

NEWEST MEMBERS OF THE BP TEAM



The BP scientific team on Calvin Laboratory's third floor in Berkeley has reached a total of 15 with the recent addition of these seven new staff members. They are (from left) Biochemical Engineer Chris Roberge, Research Portfolio Analyst Patrick Vagner, Catalysis Chemist Joseph Binder, Biofuels Regulatory Affairs Manager Ruth Scotti, Senior Research Chemist Eric Mack, Senior Biochemical Engineer Jose Escovar-kousen, and Biochemical Engineer Xiaomin Yang.

TWO EBI STUDENTS HELP INAUGURATE BRAZILIAN BIOFUELS COURSE

For two graduate student researchers in the EBI, a summer trip to Brazil resulted in contracting a flu bug and fighting its symptoms for almost two weeks. But their knowledge gained about Brazilian biofuels was just what the doctor ordered.

"I found it great to network with people in universities or companies doing similar work," said second-year molecular biology Ph.D. candidate Chris Phillips, who works in Michael Marletta's laboratory at the EBI. And fellow Ph.D. student Abigail Martin agreed. "For me, the most valuable aspects were making new Brazilian contacts that work on similar issues," said the young doctoral student in environmental policy who works on Berkeley investigator Dick Norgaard's team. "I had the opportunity to talk with Brazilian professors candidly about overlaps in our research, and they were able to provide good insights, which I otherwise would be unable to find in the white and grey literature."

They were among the 30 students selected to participate in the first Brazil-U.S. Higher Education Council short course on biofuels technology. Their classroom experience was funded by the Fulbright Commission for Educational Exchange between the two countries to promote improved communications between scientific institutions in the area of biofuels.

From July 27 to Aug. 7, the students attended classes at the University of Sao Paolo and heard presentations on all aspects of biofuel production—feedstocks, conversion technologies, economics and politics, biorefinery systems, sustainability, and life cycle analysis. Sprinkled through the schedule were various field trips and enough free time to mingle with faculty and students.

"My favorite activities were the field trips and the opportunity to talk with professors," said Phillips, who is studying accessory enzymes involved in cellulose degradation by fungi. "They had a rotation of interesting people, and the opportunities for one-on-one lunches and conversations over coffee were great."

He said he especially enjoyed observing Brazilian efficiency in producing ethanol from sugar cane. A one-day tour took students through the entire process, from the cane fields and plant breeding operations through the harvesting, transport, milling, juicing, separating, fermentation and distillation. "Brazil has it figured out," Phillips said, "achieving crop production at a reasonable price." The country's next challenge, he noted, was to convert the tons of dried waste bagasse into fuel.

Three in the inaugural biofuels short course presented in Sao Paolo, Brazil this summer, all graduate students from Berkeley, toured an ethanol fermentation facility while there. (From left) Chris Phillips and Abigail Martin work in EBI programs; Anand Gopal studies in the UC Berkeley Energy Resources Group.

Martin, too, was impressed with what she saw. "The Brazilian 'triple helix' culture of government, universities and industry relations is impressively coordinated," she said. "Understanding the changing technological landscape in Brazil is very relevant for our work on environmental and social impacts of biofuels."

Norgaard, fellow Berkeley professor Alastair Iles, and graduate students Martin, Avery Cohn and Barbara Haya are working on the EBI project "Contextualizing Bioenergy Production: Life Cycles, History and Change in Brazil." Brazilian professors and former UC grad students Renata Andrade and Sergio Pacca are collaborators.

Many institutions from both countries were represented among the students and faculty. Phillips noted that "it was obvious EBI's leadership (in biofuel research) is recognized."

Also among the students was a third Berkeley Ph.D. candidate, Anand Gopal, of the Energy and Resources Group.

DOE UNDER SECRETARY VISITS EBI IN JUNE

As part of her June tour of west coast research facilities, U.S. Department of Energy Under Secretary Kristina Johnson stopped for a visit and tour of the Energy Biosciences Institute in Berkeley. EBI Director Chris Somerville points out some of the lab's major features during a walk-through of Calvin Laboratory. Johnson was previously Provost and Senior Vice President at Johns Hopkins University.

VISITING PROFESSOR SHEDS LIGHT ON COMPLEXITY OF CELLULOSOME FUNCTION

Raphael Lamed is an internationally recognized authority on cellulolytic bacteria and a pioneer in the discovery of cellulosomes—those multienzyme complexes implicated in the degradation of plant cell walls.

The EBI's first sabbatical visiting professor, Lamed—from the Department of Molecular Microbiology and Biotechnology at Tel Aviv University in Israel—spent a year with his colleagues at Berkeley working toward a deeper understanding of the way specific complex molecules bind to cellulose and trigger the deconstruction of biomass into sugars. Energy Biosciences Institute researcher Jamie Cate from UC Berkeley heads a team that is looking into optimizing cellulosomes for biofuel production.

Before returning home, Lamed gave a detailed presentation on structural diversity in cellulases. The multiple subunits of cellulosomes are composed of numerous functional domains that interact with each other and with the cellulosic substrate, he noted. The complex of proteins includes carbohydrate binding modules (CBM's), dockerins, cohesins, and scaffoldin. Some enzymes bind to the cellulose and initiate deconstruction; some don't. The holy grail for Lamed and his colleagues is to figure out which ones bind, why, and how.

Right now he's honing in on the CBM3 family of modules, which have been shown to have special properties for attaching to and cleaving the cellulose chain. Lamed is engaged in a systematic structural investigation of CBM3's and their roles in cellulosomes.

He is also investigating a fiber-degrading bacterium in cow rumen, Ruminococcus flavefaciens, which exhibited a most elaborate cellulosome system that included 50 different enzymes, 230 dockerin-bearing proteins, and 10 cohesin-containing scaffoldins that can bind the dockerins. Gene clusters were compared with other bacterial strains to determine homologous segments that might be central to the deconstruction of plants in rumen.

Lamed's painstaking search is reflective of the many complex challenges faced by investigators as they try to find ways to simplify the bioconversion process in plants.

UC BERKELEY/ITT-KHARAGPUR, YEAR 2

The EBI's group of seven summer students from the Indian Institute of Technology in Kharagpur this year included the three shown here with host faculty member Manfred Auer: (from left) Shailabh Kumar, EBI principal investigator Auer from Berkeley Lab, Dolonchampa Maji, and Gourab Chatterjee. This was the second year of collaborative student exchange between UC Berkeley and ITT, featuring 18 total students for the eight-week summer research program.

ILLINOIS SEMINAR SERIES

The Energy Biosciences Institute at Illinois has announced its schedule for the fall seminar program. All talks begin at noon. The speakers, titles, and locations include:

SEPT. 16, JING DU,
Biofuels Production, "Facilitating Pentose Utilization by Introducing Pentose Transporters into Saccharomyces cerevisiae," IGB 612

SEPT. 28, MAGDY ALABADY,
Feedstock Development, "Genomic Characterization of the Miscanthus Small RNA Transcriptome and the Discovery of its Role in Biomass Deposition," IGB 612

OCT. 12, ANDY WYCISLO,
Feedstock Agronomy, "Miscanthus x giganteus Rhizome Propagation: Problems and Perspectives," IGB 612

OCT. 26, XIAOGUANG CHEN,
Economic Impacts of Biofuels Program, "Economic Potential of Second-generation Biofuels: Implications for Social Welfare, Land Use and Greenhouse Gas Emissions," Edward Madigan Lab 350b

NOV. 9, YEJUN HAN,
Biomass Depolymerization Program, "Functional Comparison of Two Mannan Degrading Enzymes from the Thermophilic Bacterium Caldanaerobius polysaccharolyticus," IGB 612

NOV. 30, MONDAY AHONSI,
Insect Pests and Plant Pathogens Program, "Survey of Bioenergy Crop Diseases: a Necessary Evil in the EBI Research Portfolio," IGB 612

STATE HURDLE CLEARED FOR NEW EBI BUILDING IN BERKELEY

The California State Public Works Board has approved a revised plan for the proposed Helios West research facility, designed to house the Energy Biosciences Institute. The new plan calls for the original one-building concept on the Lawrence Berkeley National Laboratory site to be reconfigured into two buildings, and UC Berkeley has identified a site in downtown Berkeley for the EBI facility that would also house complementary bioengineering programs.

The key funding hurdle, authorizing the previously approved sale of $70 million in state lease-revenue bonds—$40 million of which would go to the EBI facility—means the decision now moves to the UC Board of Regents. The board will consider the revised scope of work this month and, if approved, will act upon a new design in January.

Under the new plan, the EBI building will include 64,000 square feet of usable interior space that will replace the vacant State Department of Health Services building along Berkeley Way between Shattuck Avenue and Oxford Street. With Regents' approval, demolition of the eight-story structure will begin next winter. If all authorizations are received in a timely way, and construction proceeds as envisioned, the EBI could move into its new home in early 2013.

University officials decided that the first option to house the EBI and Berkeley Lab's photovoltaic and electrochemical solar energy research in a single 144,000-square-foot cantilevered building on the hillside within the Lab site—Helios—presented too many geological and cost challenges to proceed. The two-facility solution promises reduced impacts, costs and delays, according to a letter sent to the Berkeley mayor and city council, signed by UC Berkeley Chancellor Robert Birgeneau.

A second, smaller building devoted to Berkeley Lab's photovoltaic and electrochemical solar energy research, is envisioned on a UC-owned site somewhere within the lab boundaries. Four locations are presently under consideration.

In his letter, Birgeneau said locating the proposed EBI Facility in downtown Berkeley would place the facility "close to the many bioscience programs in the northwest quadrant of the UC Berkeley campus, providing the biofuels programs with broad and important research synergies. It would also improve access for students and faculty, who would be able to walk to and from the central campus."

This is actually the third go-round for Helios. An original building design near the site of Berkeley Lab's Molecular Foundry was approved by the Regents in 2007. Then, faced with unanticipated geotechnical issues, the design was streamlined from six stories to three and the site was moved slightly northwest last year. Subsequent analysis indicated that this location, too, presented expensive and time-consuming construction challenges due to a complex hillside geology. Thus campus and lab officials developed the two-building strategy.

The campus hopes to begin construction of the EBI facility by mid-2010 assuming all environmental reviews are positive.

The EBI program, now housed in Calvin Laboratory, Hildebrand Hall, and in program offices at various locations around the UC Berkeley campus, would be consolidated into the new EBI facility.

GIRLS LEARNING BIOIMAGING BASICS

EBI Graduate Student Ashley Spence (standing) assists a summer camper at the Girls' Adventures in Math, Engineering and Science Summer Bioimaging Camp in early August at Illinois. Forty-one eighth and ninth grade girls participated in the second annual weeklong camp, at the U of I's Institute for Genomic Biology. Campers addressed research questions, collected and analyzed data, and ended the week with a poster session. Spence taught the girls how to use the apotome microscope and how to run image analysis software.

SEMINAR SERIES (CONT'D)

One of Hazen's co-PIs, December speaker Coates, is a professor of microbiology who is looking at flow rates and mechanisms within oil reservoirs.

Leschine is a professor of microbiology who is researching the physiology, genetics and ecology of polysaccharide-fermenting microbes. Her primary focus is on a species of Clostridium which produce ethanol as a product of cellulose fermentation.

Gould is Director of the Texas AgriLIFE Research facility in Weslaco, TX. Molecular biologists and plant scientists are researching next-generation crops for new markets such as biofuels.

He is a former Vice President for Research at the U.S. Sugar Corporation in Clewiston, Florida, and Director of Research for Biotechnology Research and Development Corporation in Illinois.

All seminars in the 2009-10 series will be videotaped and posted on the EBI web site.

Suggestions for future speakers can be sent to Susan Jenkins, EBI Assistant Director, at SJenkins@berkeley.edu.

In the Trenches:

THE PROGRAMS AND PROJECTS OF EBI

The seventh of a series of profiles about the people doing work in the Institute, designed to familiarize research teams with colleagues' efforts and thus provide potential areas of collaboration and communication.

ALEXANDER KATZ: ENHANCING BIOFUEL PRODUCTION VIA RATIONAL DESIGN

UC Berkeley chemical engineer Alex Katz (right) receives a report from postdoc Ted Amundsen. Katz is Principal Investigator of the "Enzyme-Inspired Catalysts for Enhancing Biofuels Production" Research Program in the EBI.

The modern-day alchemists in Alexander Katz' UC Berkeley laboratory are concentrating on the engineering of catalysts—those chemical substances that, like enzymes in plants, trigger biological transformations necessary in the conversion of biomass to fuel. It's a tricky balancing act of organic and inorganic substances, but an essential one if the biofuel process is going to be economically viable.

"People have used a variety of approaches for processing biomass to biofuel," said chemical engineer Katz, principal investigator for the EBI project Enzyme-Inspired Catalysts for Enhancing Biofuels Production. "For example, they will use heat to create a thermal reaction, but that's typically not very selective. You will sometimes lose one-half or more of the product to waste material. You can't afford to throw away so much fuel."

What is needed, Katz said, is a system that induces transformations, like hydrolysis and depolymerization, rapidly and with minimal loss of biomass. Enzymes perform these functions expertly in nature, but "no one really knows exactly how enzymes work the way they do," he said. "Biocatalysts can do these transformations with high selectivity. We are looking at the mechanisms being postulated, to see if we can develop synthetic systems with improved selectivity and efficiency."

Right now, the Katz team is focused on "bifunctional catalysis," a procedure that involves the use of both acids and bases in a delicate push-pull of electron density. The idea is to develop a catalyst that will break the carbon and oxygen bonds in cellulose and lead to their reassembly as fermentable sugars in the fuel production process.

"The organization between acid and base needs to be just right, and the requirements are very stringent—a shift of plus or minus one angstrom (the size of an atom) can sometimes make a difference," said Katz. Combine that with the variations presented by biomass feedstocks, and the challenge of making effective synthetic catalysts becomes intimidating indeed.

Their novel approach to the problem involves the use of cellulosic organic and inorganic hybrid materials, creating composites that enable "cooperative catalysis" like natural enzyme mechanisms employ. The role of the biomimetic aspect is to offer new chemically selective conversion systems. Katz's group has already had success in building prototypes of these materials that push these approaches into the realm of emerging and promising methods for biomass pretreatment and cellulose dissolution, depolymerization, and deoxygenation.

It's new territory for Berkeley's chemical engineers, but early results show promise on model systems. Katz, research specialist Andrew Solovyov, and postdocs Tatiana Luts, Ted Amundsen and Brandon McKenna are convinced that catalysts-by-design will enhance biofuels production in unprecedented and innovative ways.

STEVE MOOSE: USING GENETIC MAPS TO FIND THE IDEAL BIOFUEL FEEDSTOCK

What genetic engineering did for corn and other crops, it can also do for emerging biofuel feedstocks, says Steve Moose, associate professor of crop sciences at the University of Illinois and EBI principal investigator for the project: "Genomics-Enabled Improvement of Andropogoneae Grasses as Feedstocks for Enhanced Biofuel Production."

"We've got the pieces; now we just have to put them together," he said. "It's like a puzzle. A bacteria (genome) would be like a 500-piece puzzle. This is like a 50,000-piece puzzle." His four co-PIs, four scientists, three postdocs, three graduate students, a computing specialist, and an undergraduate need to hone in on the 5 percent of the sequenced bases that are actually "gene space," where the relevant genes are expressed. The rest are repeated sequences of little value in trait identification.

Members of the "Genomics-Enabled Improvement of Andropogoneae Grasses as Feedstocks for Enhanced Biofuel Production" project in the EBI include, from left, Principal Investigator Steve Moose, Magdy Alabady, Won Byoung Chae, Adam Barling, Brandon James, Co-PI Ray Ming, Arthur Rudolph, Ornella Ngamboma , Brandon Smith, Kankshita Swaminathan, Jack Juvik, and Cuixia Chen.

"Our goal is to look at the genes that underlie interesting traits," said Moose of his team's efforts to sequence and map the Miscanthus genome. "Twenty-first century crop improvements are gene and biology driven."

He should know. Moose has been at the forefront of research on the molecular mechanisms that regulate gene pathways in maize. He and his Illinois colleagues have contributed significantly to improvements in corn, soybean, and rice crop production through the application of genomics tools to plant species. Transgenic varieties have higher yields, are more resistant to disease, and maximize nutrient intake.

Miscanthus, however, will be a different challenge. You can fit three corn-sized genomes into the Miscanthus giganteus genome. It has 7.5 billion bases—letters that spell out the genetic code—and when completed it will be the first perennial grass, and the biggest plant genome, ever sequenced. Working with the Joint Genome Institute and UC Berkeley molecular biologist Dan Rokhsar, Moose said he hopes to finish a draft of the Miscanthus genome next year.

Kankshita Swaminathan works with Miscanthus DNA in the Moose Lab.

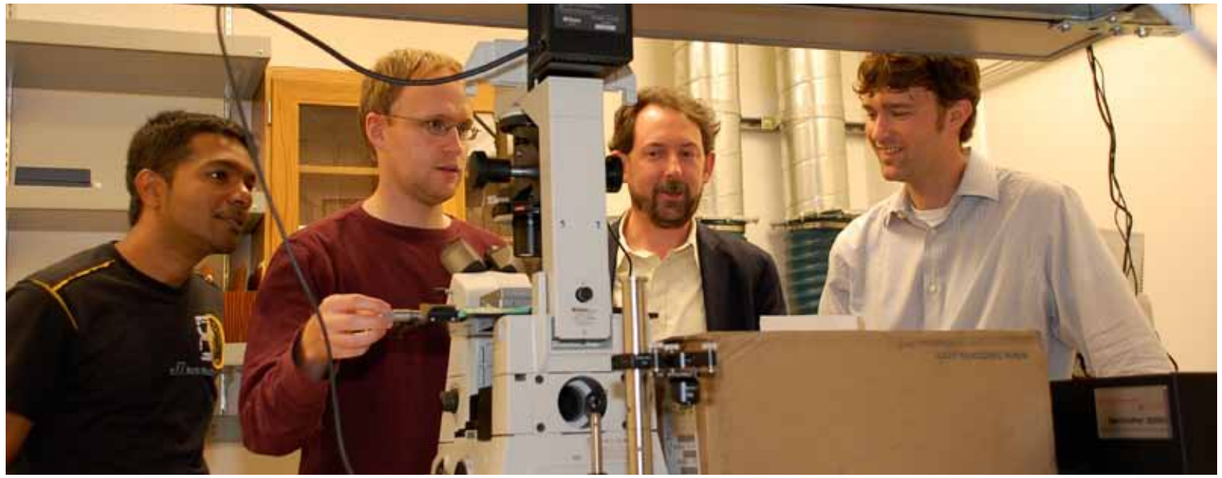
Which functional traits? Moose cites at least four to which gene matches will be sought—the concentration and storing of carbon, flowering, nutrient cycling, and disease and pest tolerance. With genetic knowledge and the manipulation tools available to biologists today, crop variations can be developed that maximize each trait and growth potential in different regions and climates.

A close relative of Miscanthus, Saccharum or sugar cane, will also be genetically mapped by the group. The Andropogon grasses are generally tall and hardy plants with enough biomass to warrant a close look as an ideal feedstock for cellulosic biofuel production. They yield so-called C4 and C5 sugars, which then can be fermented into fuel.

At the June EBI retreat, Moose pointed out that in some parts of the world, public perception has held back the power and potential of biotechnology, and "we don't want to see that with biofuels." Today, he said he believes "people are more accepting (of biotechnology), but there will always be someone who raises controversy. It's been useful in agriculture throughout the world, and since we won't be developing food crops, people may not have an issue with it."

To Moose, the full value of recent investments in plant genomics will only be realized if researchers are trained in the application of genomics tools to crop plant species and the benefits of plant biotechnology are effectively communicated to the public.

PAUL ADAMS: LOOKING AT THE PLANT CELL WALL IN A DIFFERENT LIGHT



RAMAN SPECTROSCOPY TEAM IN BERKELEY FEATURES PRINCIPAL INVESTIGATOR PAUL ADAMS (SECOND FROM RIGHT) AND BERKELEY LAB COLLEAGUE JIM SCHUCK (RIGHT). POSTDOC MARTIN SCHMIDT USES THE LASER AS GRADUATE STUDENT PRADEEP PERERA (LEFT) LOOKS ON.

Prior to 2006, Berkeley Lab Senior Scientist and UC Berkeley bioengineer Paul Adams was focusing his research on structural biology, in particular in developing computer software and other tools to enable the characterization of proteins. Then two things happened.

First, Adams met plant scientist Chris Somerville of Stanford University at a bioenergy forum assembled by then-LBNL Director Steve Chu. They talked about the problems associated with understanding the synthesis of the plant cell wall. Then Adams co-organized a bioimaging workshop on campus and learned about the potential for chemical spectroscopy at the nanometer scale.

"I found the problem (of the cell wall) interesting, even though I didn't have a background in plants," Adams recalled. "It is a complex mixture of chemical polymers, forming a matrix that isn't amenable to many imaging techniques. I heard about Jim Schuck's work on Raman imaging of materials, and I thought it might be possible to adapt it for biological samples."

Schuck, a materials scientist at the lab, then joined with Adams to write a proposal for the EBI that became one of two programs dedicated to deciphering the architecture and chemical composition of the cell wall. The conversion of cell wall cellulose and hemicelluloses to sugars is central to biofuel production. Fellow LBNL microscopist Manfred Auer leads the other program, which is seeking to image the cell wall using electron microscopy. The programs are working closely together to combine results to develop a 3-D map that shows both structure and chemistry.

Raman imaging is a technique that relies on scattering of monochromatic light, like that from a laser, and the subsequent energy measurement of the shifting photons and vibrating molecules at the sample's surface. Adams' program performs micro-Raman spectroscopy – with image resolution of about 500 nanometers– using a new laser microscope in Calvin Lab on the Berkeley campus. Up the hill at Berkeley Lab, Schuck and other members of the team are using tools in the Molecular Foundry to develop Raman imaging at the nano scale – down to a resolution of 30-50 nanometers.

Why is such modeling so important to the biofuel development process?

"The biggest thing is to get a basic understanding of the cell wall and how it is made," Adams said. "Then, if we can see how the cell wall changes (under different pretreatment conditions), and correlate this with the effectiveness of sugar release, we can help in the identification of better feedstocks and deconstruction methods. In the future, we hope to look at the changes in real time, and maybe we can be predictive about the best conversion approaches."

One of the next steps in the program, according to Adams, will be to use the Raman technique to study the effect that ionic liquids have on biomass during pretreatment. An understanding of how these agents solubilize the cellulose could help to define the best ionic liquid to use among the tens of thousands possible.

As with any new research approach, the Raman spectroscopy application to bioenergy presents its challenges. Nano-Raman imaging involves the making of tiny gold antennae, facing tip-to-tip, which scan across a surface and determine the chemical composition by measuring electromagnetic waves. Adams said progress is being made on producing functioning nanoantennae at the Molecular Foundry, and work is proceeding on the difficult process of ultra-thin sample preparation in collaboration with Auer's program. Proof of principle in two dimensions could come in the next year or two, with a 3-D version to follow, he said.

Micro-Raman spectroscopy also has its challenges when studying plants, since fluorescence of the green samples tends to dominate the image and swamp the Raman signal. Adams said his team is working with the Somerville group to develop model Arabidopsis plants with lower levels of green pigments, one of the main causes of plant autofluorescence.

It is a classic pairing of physics and biology, itself a model system for the interdisciplinary effort required to enable the development of bioenergy products.

Five Questions

...for Illinois Environmental Economist John Braden

JOHN BRADEN, AT LEFT, DISCUSSES THE BUSINESS OF BIOFUELS WITH GRADUATE STUDENT XIAOLIN REN.

Which biofuel feedstock is most sustainable? What policies will encourage and control biofuels most effectively? And what are the socioeconomic and environmental impacts of the feedstock-and-policy formulas that might drive the industry?

Those are some of the key questions facing principal investigator John Braden, Professor of Environmental Economics at the University of Illinois, and his team of colleagues that includes Madhu Khanna, Thomas Theis and Xiaolin Ren. Their EBI project involves developing models that will support analysis of trade-offs between carbon and nutrient emissions as biofuels grow in importance.

Since joining the Illinois faculty in 1979, Braden has been researching environmental economics and environmental policy. One focus has been the environmental conditions of the Great Lakes, which contain 20 percent of the freshwater on earth. He also works on sustainable urban development and on environmentally differentiated products, like biofuels.

Braden has taught courses in environmental economics, natural resource economics, program evaluation, operations research, research methods, and personal finance. He also co-founded the program for Environmental and Resource Economics in the Department of Agriculture and Consumer Economics, where he is Director of Undergraduate Programs.

He earned his B.A. in economics at Miami University of Ohio, and his Master's and Ph.D. degrees at the University of Wisconsin-Madison.

1. Your team is looking at various biofuel production pathways through which environmental and socioeconomic impacts will be evaluated. What are some of those pathways, and how do you expect their impacts to differ?

By biofuel pathways, we mean different bio-feedstocks and different processes that might be used to produce fuels. The range might be from oil seeds used to produce biodiesel to grains or algae for ethanol to methane from livestock wastes. As a practical matter, in this project, we are looking only at corn, switchgrass, and miscanthus feedstocks for ethanol production. The grass crops differ from one another, and from corn, in their cost of production, productivity per acre, net greenhouse gas (GHG) production, and use of inputs, especially nitrogen. Nitrogen presents challenges as both a water pollutant and as a GHG precursor (the fraction of N-fertilizer that transforms in the environment to N_2O becomes a potent GHG). Because of these differences between pathways, public policies can change their relative economic viability.

2. Your models will include economic inputs like energy taxes, biofuel subsidies, and agro-environmental subsidies. How sensitive is the biofuel production mix to these policy factors and to technology changes?

We find that the current ethanol mandates that require 15 billion gallons by 2012, of which 0.5 billion are from cellulosic feedstocks, will actually increase total fuel use while reducing GHG emissions on the order of 2 percent and increasing nitrogen fertilizer use by 15 percent. Coupling the current subsidies with those mandates will have almost no effect on the environmental outcomes while providing large transfer payments to producers. However, using a carbon tax (or any policy that puts a price on carbon) in lieu of subsidies would reduce total fuel use while also reducing GHG emissions and limiting the increase in nitrogen. These conclusions are valid when there is no technology change in the cellulosic ethanol sector. However, as cellulosic ethanol production becomes more cost-competitive, cellulosic ethanol could take more market share to meet the ethanol mandates, which would have larger benefits in terms of GHG emissions and nitrogen use. Appropriate assumptions on reasonable technology changes are required to conduct this analysis.

(continued on pg. 11)

EBI ENERGY FARM STAGES FIRST-EVER OPEN HOUSE IN AUGUST

University of Illinois Ag Engineer K.C. Ting, at left, Principal Investigator of the Engineering Solutions for Biomass Feedstock Program, demonstrates one of the Unmanned Aerial Vehicles that will help researchers analyze crop growth on the energy farm.

The Energy Biosciences Institute opened its crop research facility to the public for the first time on Aug. 13, and dozens of people -- including farmers, scientists, students, and administrators -- heard about the institute's plans for making biofuel feedstock crops work in the real world.

Open House visitors boarded tractors for a hands-on tour of the premises, stopping for presentations on topics ranging from fighting insect infestations to breeding plants for genetic diversity.

At the first stop, assistant professor D.K. Lee presented the farm's nursery, where recent plantings of native grasses—like switchgrass, big bluestem, Indian grass, and prairie cordgrass—are flourishing. Though the nursery was just planted this year, some grasses were already taller than the visitors eyeing them—and some, Lee joked, would soon be "two D.K. tall."

But to grow these grasses on a commercial scale, scientists first have to show farmers that they're profitable. One of the biggest barriers to making biofuel crops lucrative is the establishment period—perennial grasses usually need two to three years to start producing high yields. If farmers change their entire acreage from corn to, say, switchgrass in one planting, they stand to lose a lot of income. Graduate student Allen Parrish showed visitors a possible

Open house visitors included faculty, staff, students, and community members from across Illinois.

solution: a plot where switchgrass and maize has been planted together.

"Our goal is to help farmers make money while their switchgrass is being established," said Parrish. With this kind of crop mixing, farmers could continue to harvest corn until the grasses are mature, at which point planting perennial grasses could be economically feasible.

Ecological impact is another concern in the switch from corn to novel biofuel crops, since new plants could have unforeseen environmental implications—but they could also be more ecologically friendly than corn. At the Energy Farm, researchers have developed complex drainage and gas monitoring systems to track each crop's influence on factors like water supply, carbon emissions, and nitrogen balances.

"We want to account for everything going in and out," said postdoctoral researcher Sarah Davis. "Then we can compare side-by-side the biogeochemical cycles for each crop."

At another tour stop, professor K.C. Ting and postdoctoral researcher Tofael Ahamed echoed this emphasis on in-depth plant analysis. Their crop monitoring team's technology portfolio includes a helicopter-like Unmanned Aerial Vehicle and a remote-controlled, 360-degree, multispectral camera that sits atop a tall central tower. These machines take wide-area pictures of crops that the team will then correlate with the plants' actual biophysical properties. If all goes according to plan, researchers could eventually analyze crop growth through a set of images.

Such quick, comprehensive monitoring could be useful to researchers like Tom Voigt, principal investigator on the Feedstock Production Program, who is working to determine the optimum conditions for growing perennial grasses. In addition to comparative trials across the United States, Voigt and his colleagues have begun establishing feedstock crops at the Energy Farm. He showed visitors a plot of Miscanthus that was just planted in April; the stalks were already over four feet tall.

"This is the most successful rhizome planting the University's ever had," Voigt said. In the long term, in addition to tracking this plot's growth, his team will also look for new biofuel crops, harvesting and storage techniques, and ways to share crop data across continents.

For now, Voigt and the other Energy Farm scientists are focusing on establishing the crops and setting up the technologies for the long haul. As Davis put it, "Everything's preliminary right now—but this project is going to last 10 years." The researchers are excited to share how long-term experiments develop over time. And with one successful Open House in the books, they're already looking forward to next year's showcase.

SAFETY FIRST: TAKE COVER WHEN A TORNADO WARNING SOUNDS

Californians arriving at the IHotel in June for the Energy Biosciences Insitute scientific retreat were greeted by a couple of unsettling messages. The first was delivered by Mother Nature in the form of a thunderous storm that flooded streets and bent trees sideways.

The second was offered by EBI Deputy Director Steve Long at his welcome talk the next morning. "This is the peak season in tornado country," he told everyone. "Chicago had its worst weather of the year yesterday." And he went on to explain procedures for what to do in the event that a warning siren goes off.

Southcentral Illinois is indeed tornado country—the "season" is March through October—and EBI staff working on the Champaign-Urbana campus should be aware of the risk. Since 1950, Champaign County has experienced more than 60 tornadoes, causing two deaths, 55 injuries, and $42 million in damage. In the decade ending in 2007, the state had 640 reported tornadoes, causing 19 deaths and 288 injuries.

Although the campus has not experienced any major damage or injury, there have been close calls. In 1996, a strong tornado moved from the north edge of Savoy to the southeast edge of Urbana. More than 30 homes were destroyed, 12 people were injured, and damage was estimated at $9 million. Others have been sighted in the area, their swirling funnel winds sounding like a freight train, only louder.

Specific evacuation and safety plans have been developed for both the Institute of Genomic Biology building, where most of the EBI programs reside, and the institute's Energy Farm. The IGB building has a designated tornado shelter area in a concourse corridor below ground, delineated by signs. The Farm office trailer has a weather radio that provides warnings of severe weather in the county.

Continuous three-minute-long sirens are activated once a funnel cloud or tornado has been sighted near campus or has touched down within Champaign or Urbana. Employees should take shelter as soon as they hear the siren, in the IGB concourse or in a steel-framed concrete building away from windows. People at the Energy Farm should not go into the fields if severe weather is in the forecast, but if caught at the farm, they should seek shelter in a nearby building or on campus.

Shelter should be maintained for at least 30 minutes, plus subsequent 30-minute periods if the siren sounds again.

Additional information is available in the "Tornado Preparedness" section of the UI Office of Emergency Planning guidelines (http://www.fs.uiuc.edu/PDFs/SC/SC-%20tornado.PDF).

EBI MOURNS SAFETY COORDINATOR JOHN PINGEL

John Pingel, the Associate Director of Operations and Facilities at the Institute for Genomic BIology at Illinois and the coordinator of safety programs for the EBI, has died after an extended illness.

"Meeting BP's expectations concerning our safety training and implementation, in an academic environment, coupled with Illinois campus requirements, appeared one of the most daunting challenges in the development of the EBI," said EBI Deputy Director Steve Long. "John took all of this in his stride, developing the training materials, procedures that met and implemented all requirements, and convinced all, in a pleasant but firm manner, of the need for all to adhere to these. The foundation that John laid is now a core and most positive part of the EBI and will be with us for many years to come. "

FIVE QUESTIONS FOR JOHN BRADEN (CONT'D)

3. You indicate that the ultimate mix of biofuel types and feedstocks will involve a tradeoff between the positive impacts on climate change and the potentially negative impacts on local water quality. Can a happy, healthy balance be achieved?

The best way to find a balance is to put appropriate "prices" on the environmental impacts and let producers and consumers make decisions that reflect both the environmental costs as well as the value in use of these fuels. This implies that a GHG tax combined with a nitrogen tax would send the appropriate signals under current technology assumptions.

4. In your "Computable General Equilibrium" (CGE) model, four regions are specified for study – United States, Europe, South America, and the rest of the world. How will consumers and products differ within these regions and environments?

At this point in the research, we are considering only the U.S. and the rest of the world (ROW). We haven't progressed to the step of disaggregating ROW. Furthermore, the data that would be required to meaningfully distinguish cellulosic biofuel potentials in other regions of the world are not available. Thus, at this point, we believe it would be a leap of faith to try to disaggregate ROW and are focusing on policy scenarios for the U.S.

5: How will the EBI, and thus the emerging biofuel market, benefit from the analysis that your team will produce? What are the primary outcomes you seek?

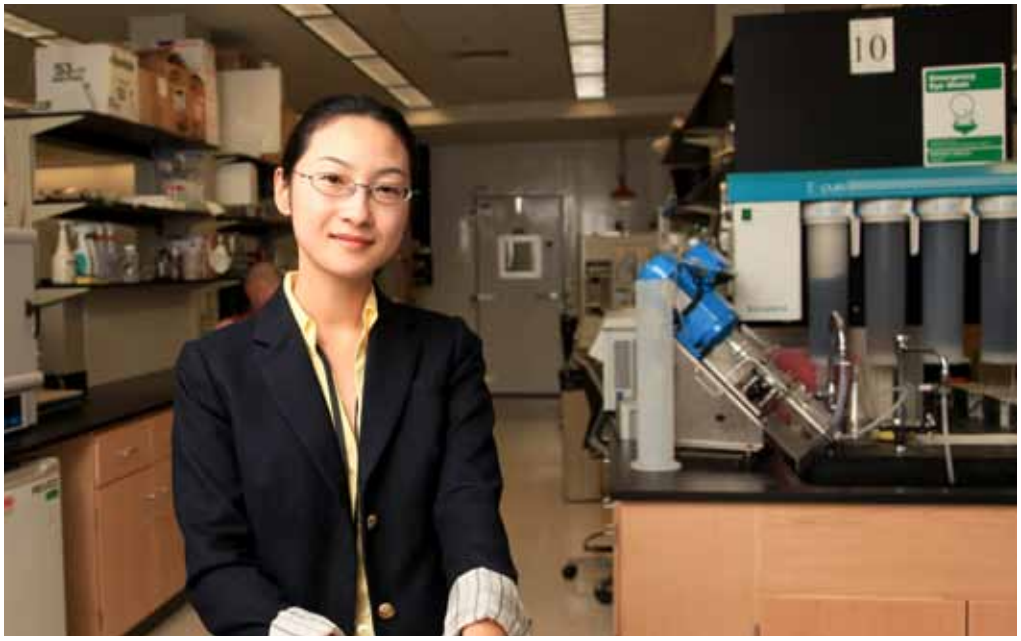
This project evaluates the competitiveness and sustainability of different biofuel pathways by evaluating their responses under different policies. The result could provide some insights for research and investment directions under current policy schemes. At the same time, this project also assesses some policies that have been proposed but aren't currently employed. These include carbon taxes (equivalent to market prices emerging in a cap-and-trade system) and nitrogen taxes. We are primarily interested in the effects of different policies on overall energy production, the amount and mix of biofuel feedstocks, GHG emissions, and nitrogen use. Knowing the responses of the biofuel pathways under possible policies will help to identify policy risks confronting investments in research and technology and to quantify the importance of production costs in market adjustments to policies.

LAB MANAGERS: KEEPING THINGS IN ORDER AT THE EBI (CONT'D)

someone came to me and said one of the autoclave machines was broken. So I called up the facility staff to arrange a repair." Just another thrilling day in the life of a fixer.

Their responsibilities cover a wide range of administrative and scientific duties. The lab managers serve as scientific resources to the researchers, and help with instrument use, questions on lab protocols, and data analysis. In addition, they are connecting elements, enabling the type of interactivity upon which the EBI mission was established. "Even though people are working side-by-side or in the same vicinity, they may have no idea what other researchers are doing," said Bryan. "I foster cross-talk between groups and get feedback from them." She maintains a biweekly lunch seminar series throughout the year in which the lab scientists share results of their work with their colleagues. It allows them to understand complementary experiments as well as to see how all the pieces fit together. Illinois sponsors a similar internal briefing series.

With this cohabitation arrangement comes some unique challenges, one being the maintenance of shared space. Bryan calls it "the tragedy of the commons," in which common areas may be littered with trash, scales and balances are uncleaned, and plates and cuvettes are left behind. So she patrols frequently, reminds regularly, and ensures that the labs on the first through third floors of Calvin Laboratory are orderly and functional.



Jing Dong, new EBI lab manager at Illinois

Similarly, Dong sees her role as a lot more than keeping track of broken instruments. "The number one priority is lab safety," she said. "We require lab safety training before someone can begin work. What do you do with chemical and biological waste? My role is to tell them the proper procedures to go through." And Bryan agrees, monitoring everything from appropriate footwear (no open-toed shoes or shorts) to proper sharps disposal.

Both Bryan and Dong are new to biofuels research and to lab management. Bryan was a postdoc working in the field of fisheries and wildlife at Michigan State University until the end of 2007, and moved to the Bay Area when her husband, Andrew Duryea, was offered a transfer to Bayer Pharmaceuticals in Berkeley. Dong was finishing a master's degree in environmental health and sciences at UC Berkeley when her husband, Gang Liu, was hired as assistant professor in the University of Illinois' Department of Electrical and Computer Engineering.

For Bryan, the chance to continue working in an academic environment was a major attraction of the EBI position, plus "biofuel is an interesting and relevant field," she said. And for someone who had spent all of six days in California (she grew up in New Jersey, went to college at Rice University in Texas, and earned her Ph.D. from Michigan State University) prior to moving there, she admits to acclimating to the weather, recreational opportunities, and food scenes quite easily.

Dong is admittedly new to lab management and still in the midst of learning names, taking orientation classes, and studying bioenergy. She graduated in biotechnology from Huazhong University of Science and Technology in Wuhan, China in 2001, then studied physiology for two years at the University of Miami before moving to Berkeley in 2004.

Both Bryan and Dong bring their backgrounds in bench science to their responsibilities as instrumentation experts, scientific resources, safety officers, organizers, mentors, and "go-to" problem-solvers for the scientists in the EBI. They are each an essential nexus for program coordination and interdisciplinary cooperation.

THE EBInsider

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