Standing on the Shoulders of Giants

The Michigan Agricultural Experiment Station's rich history of excellence and innovation makes MSU unique among state research institutions

The MAES, created on Feb. 26, 1888, by the federal Hatch Act, has a 120-plus-year history of pushing the boundaries of research to explore new frontiers and develop technologies that have become commonplace in society. Throughout the years, the MAES has funded the visionary work of scientists whose ideas sometimes were met initially with uncertainty but ultimately led to advances that have benefited people around the world.

For example, when MAES microbiologist and molecular geneticist Mike Thomashow came to MSU in 1986, there was a lot of skepticism in the scientific community about whether his chosen line of investigation, the study of cold-regulated gene expression, could offer enough information and knowledge to provide significant new insight into the genetic basis of freezing tolerance.

Today, Thomashow is recognized around the globe for his work on the molecular mechanisms of cold acclimation and drought tolerance in plants.

Ten MSU faculty members have been elected members of the National Academy of Sciences in the history of the institution. Of these 10, four — Pam Fraker, Richard Lenski, Jim Tiedje and Mike Thomashow — are current MAES faculty members, and three — Jan Zeevart, Edward Tolbert and Martin Bukovac — are former MAES faculty members. Election to the academy is considered one of the highest honors that can be accorded a U.S. scientist or engineer.

In 2007–08, MSU was granted 37 patents; 25 of those patents were led by MAES faculty members. In 2006–07, MAES scientists were responsible for 14 of 35 patents awarded to the university.

Approximately 75 percent of the MSU faculty members associated with the Great Lakes Bioenergy Center (GLBRC) are MAES faculty members. MSU and the University of Wisconsin-Madison are partners in the GLBRC, one of three U.S. Department of Energy Bioenergy Research Centers created in 2007. Based in Madison, the center is funded with $125 million over 5 years. MSU is using approximately $50 million for basic science research aimed at solving some of the most complex problems in converting natural materials to energy, and MSU recently received approximately $2 million in new GLBRC funding to study the environmental benefits and consequences of cellulosic biofuel crops.

As of August 2009, the MAES funded the work of almost 400 scientists (383 to be exact) in six colleges at MSU: Agriculture and Natural Resources, Communication Arts and Sciences, Engineering, Natural Science, Social Science, and Veterinary Medicine.

"The Michigan Agricultural Experiment Station is doing a great job," said MSU Provost Kim Wilcox. "In these trying budget times, the university has to rely on its strengths, and the MAES is one of our strengths. We are expecting more of it now than ever."

"The MAES is ranked as one of the top experiment

MSU provost Kim Wilcox, MAES associate director John Baker and MSU vice president for research and graduate studies Ian Gray *(left to right)* discuss how the Michigan Agricultural Experiment Station fits into the Michigan State University research portfolio.

KRIS BERGLUND

Welcome to Fermentation Station

What do a salt substitute, distilled spirits and the chemical intermediate succinic acid have in common? They are all natural products created from fermentation processes developed over the past 20 years by MAES forestry and chemical engineering and materials science researcher and MSU distinguished professor Kris Berglund.

"The basis of all this work has to do with some sort of fermentation process," Berglund said. "We start out with a basic idea that can be applied to a variety of renewable resources — for example, starch from grains and corn, cellulose [residues extracted from plant stems and stalks that aren't food products] and hemicellulose from forest products. We have a number of raw materials we can choose from and five or six fermentations we are studying."

One of the most notable products in Berglund's research portfolio is a salt substitute commercially known as AlsoSalt. The notion for this product came from Berglund's knowledge of the five tastes identified in Japanese science — bitter, salty, sour, sweet and umami (which means "savory" or "deliciousness").

"Umami is the sense of flavor enhancement," Berglund explained. "MSG is the classic umami flavor – it intensifies the taste of food. As it turns out, lysine — an amino acid that is one of the major products fermented from corn starch — is mildly salty and also possesses this umami flavor. We were already studying lysine, so we asked what the basic problem was with salt substitutes. The answer is that they have a bitter taste that needs to be masked."

Their interest piqued, Berglund and his colleagues started testing lysine and a number of other amino acids.

"It wasn't some great hypothesis — we just tasted things and figured out what tasted salty and what didn't, what masked the bitterness and what didn't," Berglund said. "Through trial and error, we came up with a particular formulation of potassium chloride and lysine that gives the salty flavor without having any salt in it. That's what AlsoSalt is."

Patented in 1999, AlsoSalt was introduced to the U.S. market 5 years ago. This spring, Heinz announced that it was using AlsoSalt in a reformulated version of its no-salt ketchup.

"When we started this work, most people were interested in artificial sweeteners — they didn't care about salt," Berglund continued. "Now there's a much stronger appreciation of the health effects of sodium in people's diets."

Berglund's research contributions reach beyond product development. Legislation passed in Michigan last year that allows small distillers to market and sell their products on site was based on 11 years of research by Berglund. The law, the most producer-friendly of its kind in the country, is expected to bolster the state's economy by encouraging entrepreneurs to start distilling businesses in Michigan.

Berglund's work has also spawned enterprises in Michigan, Sweden and France.

"Our main objective is to use fermentation processes to add value to agricultural and forest products," Berglund said. "We're taking renewable resources and turning them into high-value, high-quality products that serve to further Michigan's bioeconomy."

— VAL OSOWSKI

stations in the country," said J. Ian Gray, MSU vice president for research and graduate studies and MAES director from 1996 to 2004. "The MAES captures research strengths across the institution and harnesses them to serve the mission of the MAES and the university as a whole. It's a catalyst for multidisciplinary research in cutting-edge areas."

MAES administrators agree that maintaining excellence requires an ongoing prioritization and evaluation process, as well as seeking out the best minds in established and emerging research fields. The MAES prides itself on being flexible and willing to fund research that some might consider outside its traditional purview.

"The MAES captures research strengths across the institution and harnesses them to serve the mission of the MAES and the university as a whole."

— IAN GRAY

"We're constantly looking at the research and researchers we fund and considering how it all fits into the overall mission of the MAES and the university," said John Baker, MAES associate director. "We want to be ahead of the curve, providing technology and information to policymakers, industry and the public before the need is recognized."

A recent example is research started 10 years ago by Ray Miller, who oversees forestry research at MAES properties in the Upper Peninsula and serves as director of the U.P. Tree Improvement Center (UPTIC), one of 15 MAES field research stations. In September 2008, Miller was named MAES forest biomass development coordinator in recognition of the growing importance of using trees as raw materials for biofuels and bioenergy. But Miller's foresight in this area reaches back to 1988, when, soon after being named UPTIC director, he planted clone trials of poplars and willows, two tree species that show the most promise for the biofuel market. In 1997, he put in a poplar plantation that was harvested in the fall of 2007, providing the first and only hard data on yields of trees grown specifically for biofuel production in Michigan. The data is being used to build computer models to simulate production under various conditions. Because of this, Miller and MSU have developed several research partnerships with companies such as the Mascoma Corporation, which is working to create a commercial cellulosic biofuel production plant, and other companies developing wood-fired power plants.

"It's quite impressive how Ray has refocused much of the research at UPTIC on cellulosic biofuels," Baker said. "The work up there is now more interdisciplinary and aims to study issues that have become hugely important to Michigan in the past few years."

Another example is a 4-year, $5.4 million grant through the U.S. Department of Agriculture Cooperative Agriculture Project (CAP) to improve the quality, yield, drought tolerance and disease resistance of potatoes and tomatoes. Led by two MAES scientists — Dave Douches, MSU potato breeder and crop and sciences researcher, and Robin Buell, plant biology researcher — the project will use DNA sequencing data to improve potato and tomato varieties. The largest of the nine grants awarded, the MSU grant is the first non-grain, non-forestry project funded through the CAP program and the first that is working on two species.

"It's extremely gratifying to see this innovative and important research be acknowledged and supported by the USDA, and it is a testament to the caliber of researchers we have in the MAES and at MSU," said MAES director Steve Pueppke. "Research funding at this level is essential to improving agricultural efficiency and sustainability and addressing critical and emerging national priorities and needs."

"These are the types of projects the university needs MAES scientists to lead," Gray added. "MAES faculty members have the potential to interact with a large cadre of non-MAES scientists on campus, which helps expand the mission of the MAES as well as interdisciplinary research at MSU."

"The MAES has a unique role at MSU because it has a presence across the state through the field stations," Wilcox added. "That sets up opportunities for MSU that other universities don't have."

Advancing knowledge, transforming lives

High-quality research that makes a positive difference, both locally and globally, is a critical component of the university's mission. Another is to advance outreach and economic development activities that lead to a better quality of life for

MICHAEL THOMASHOW

Beating the Heat, Conquering the Cold

After being raised and living most of his young adult life in southern California, it was a shock to MAES microbiologist and molecular geneticist Mike Thomashow's system when he moved to Pullman, Wash., for his first job in the early 1980s. It was also a turning point is his research career.

"Winter was very cold in Pullman," Thomashow recalled. "I remember looking out my laboratory window at plants surviving in minus 20-degree weather and asking myself, 'How are these plants dealing with this incredible cold? How do they overwinter in such a harsh environment?' This got me interested in understanding the genetic mechanisms that plants have evolved to withstand freezing and other environmental stresses."

When Thomashow came to MSU in 1986, there was a lot of skepticism in the scientific community about whether his chosen line of investigation, the study of cold-regulated gene expression, could offer enough information and knowledge to provide significant new insight into the genetic basis of freezing tolerance.

Twenty-three years later, Thomashow is internationally recognized for his work on the molecular mechanisms of cold acclimation and drought tolerance in plants.

One of Thomashow's biggest breakthroughs was the discovery of the CBF cold-response pathway in *Arabidopsis*, a small flowering plant related to cabbage and mustard that is considered a model organism in the study of basic plant processes.

"This is the genetic pathway that controls freezing tolerance," Thomashow said. "It also works to increase the plant's tolerance to drought and high salt concentrations. Now that we know what the pathway is, we want to see if we can influence various plant species and improve varieties."

Plant breeders at universities and private companies are now using this pathway as a type of master control switch to regulate a suite of genes responsible for dehydration stress, which can be caused by drought, freezing and/or high salinity.

Thomashow and members of his laboratory are now looking at why certain crops such as wheat, rye and canola have freezing tolerance, while others, such as tomatoes and potatoes, don't.

"Although tomatoes and potatoes have a CBF pathway, there is a deficiency in the system that prevents these plants from developing freezing tolerance," Thomashow said. "We are currently experimenting with a wild tuber-bearing variety — *S. commersonii* — that can cold acclimate to help us determine whether the CBF cold-response pathway of potatoes and tomatoes can be altered to improve their cold tolerance.

"Ultimately, the goal is to increase drought and freezing tolerance so that there is a longer growing season and an expanded growing region for as many crops as possible," he said.

— VAL OSOWSKI

RICHARD LENSKI

Evolution in Action

Evolution takes on a whole new look and feel in the work of MAES evolutionary biologist Richard Lenski. Most evolutionary biologists study evolution by examining fossils or by comparing different species. Lenski studies evolution by doing experiments with fast-reproducing organisms where he can watch evolution in action.

"Evolution is like a game that combines luck and skill, and I thought that, perhaps, bacteria could teach me some interesting new games," said Lenski, who is also a Hannah distinguished professor at MSU.

In 1988, Lenski started an experiment with 12 populations of *E. coli* bacteria — all starting with the same ancestral strain and all living in identical environments — to see just how similarly or differently they would evolve. He wanted to keep the experiment going for at least a year and culture about 2,000 bacterial generations. Twenty-one years and almost 50,000 generations later, the experiment is still growing strong.

Lenski's laboratory received quite a bit of attention last year when one of the 12 populations of *E. coli* being studied evolved the ability to eat a chemical called citrate — a compound that, until now, *E. coli* could not grow on.

"This development was particularly exciting because it showed that, in a relatively short period of time — a couple of decades — a brand new function could evolve," he said.

Although Lenski does basic research, his work has led others to think about various applications, including microbial forensics, strain improvement and computational evolution.

"After the anthrax attacks that came soon after the 9/11 terrorist attacks, it became imperative to understand how to track the source of bacterial populations that might be used in bioterrorism," Lenski said. "Because of this long-term experiment, we now have the best data on how quickly strains change at the genomic level and how much genetic variation exists within a sample. This study has become a reference point for understanding the evolution of other bacteria."

Further, Lenski said, it's increasingly recognized that evolution can be used alone or, better, in combination with genetic engineering to produce bacterial strains that have desirable features such as the ability to produce alternative fuels or remediate pollution.

Lenski's work also crosses over into in the digital world. Over the past decade, Lenski has teamed up with MSU computer scientist Charles Ofria and MSU philosopher Rob Pennock, as well as Chris Adami, a physicist from Keck Graduate Institute in Claremont, Calif., to study computer programs that self-replicate, mutate and evolve the ability to do new functions.

"Computer scientists and engineers are looking to evolution to inform their endeavors and garner new ways of solving problems," Lenski said. "My colleagues have developed software that can be used to demonstrate and explain evolutionary mechanisms and help develop new technologies in the areas of networks, communication systems and robotics. Darwin would be amazed to see where his ideas have led."

— VAL OSOWSKI

"We want to be ahead of the curve, providing technology and information to policymakers, industry and the public before the need is recognized."

— JOHN BAKER

people and communities at home and around the world. The Carbon2Markets program, led by MAES forestry scientist David Skole, fulfills both of these goals. Carbon2Markets uses basic and applied research to simultaneously fight global warming and poverty, improving people's lives and helping to protect the planet.

By combining sustainable forest management and remote-sensing technology with emerging carbon markets, Skole and the rest of the Carbon2Markets team are helping small farmers in developing countries grow crops that slow climate changes as well as improve the farmers' standards of living. The MSU team is working with farmers, researchers and government agencies in 10 African and Asian countries, including Thailand and Laos.

The farmer groups are integrating high-value forest crops, such as jatropha, teak or shea, into the crops they're currently growing using methods that are smart and sustainable. Then the farmers use techniques and standards created by MSU remote-sensing experts to accurately measure and record the carbon stored by the trees and soil. Storing carbon in the soil and plants keeps it out of the atmosphere, which helps slow global warming. This also is one of the first efforts to help small landowners gain access to the carbon offset market.

The farmers also use and sell the forest products they grow. Jatropha tree nuts can be used to make biodiesel, which is then used to run farm equipment or produce energy for a village. Shea tree nuts yield shea butter, a staple ingredient in high-end moisturizing lotions and other cosmetics. The trees also provide food, timber, firewood and medicines.

MSU was founded on the idea that practical knowledge could be combined with traditional scientific and classical studies. Skole said that the Carbon2Markets program is the application of more than 20 years of basic research on climate change and tropical forest conversion. In other words, the MSU scientists are applying basic research and remote-sensing technology to develop creative solutions to climate change. These solutions involve, educate and improve the quality of life of people who are counted among some of the world's poorest — the average annual income in the area of Thailand involved in Carbon2Markets is about $1,200.

Closer to home, MAES chemical engineering researcher Dennis Miller's work in Michigan to demonstrate the feasibility of small, local canola biodiesel cooperatives parallels the Carbon2Markets work in developing countries. One of Miller's collaborators, visiting researcher Lars Peereboom, is working with Skole to set up oil processing equipment in Thailand. Miller and Peereboom bought and set up a machine to crush canola seeds at the Michigan Brewing Company in Webberville. They figured out how to run it optimally and meet American Society for Testing and Materials (ASTM) standards for biodiesel.

"In these tight budget times, expectations are going up across campus," Wilcox said. "As a university, we have to rely on our strengths, and the MAES is one of those strengths. The MAES has unique resources, such as the field stations and the ability to offer joint appointments. All of these help the MAES act as a bridge to interdisciplinary research and catalyze thematic research on key issues."

"The MAES is coming to terms with the globalized world of the 21st century, our role as part of the modern research university, and our complex and interrelated food, agricultural and natural resource system," Pueppke said. "We have built a powerful basic research engine and focused it on problems that need solving. We have discovered expertise across the campus and used MAES resources to apply it to issues that are important to Michigan. The MAES will be a leader as we work through these complexities."

— Jamie DePolo

JIM TIEDJE

Sleuthing the Mighty Microbe

For more than four decades, MAES crop and soil sciences researcher and university distinguished professor Jim Tiedje has been studying the hidden world of microscopic creatures such as bacteria, fungi and viruses to better understand microbial processes in nature.

"The microbial world is hugely diverse," said Tiedje, who is also director of the Center for Microbial Ecology at MSU. "Some microbes can cause disease, and some carry out very valuable processes. The challenge has always been how to detect them."

Scientists began to make significant progress in microbial analysis in the late 1990s when genetic analysis and the identification of molecular markers at the DNA level opened the door to the use of miniaturization processes and microfluidics — the science of designing, manufacturing and formulating devices and processes that deal with microscopic amounts of fluid.

These innovations greatly enhance the sensitivity, speed and sample output of genetic analysis and pathogen detection. The development of tools such as DNA chips and lab-on-a-chip-type devices take advantage of such miniaturization technologies.

Tiedje and MAES environmental engineering researcher Syed Hashsham are using a gene sequence database to develop probes (molecules that identify a certain signature sequence of DNA) and primers (molecules that copy DNA) that are then dispensed in the chambers of multifluidic devices to detect pathogens.

"These devices, which are much like a miniaturized plumbing system, allow us to follow chemical reactions at a scale that is 100 to 10,000-fold smaller than was possible with traditional analysis," Hashsham said. "This technology also lets us screen for multiple pathogens and antibiotic resistance at the same time, giving us the ability to examine the relationship between pathogens and potential treatment options in a faster, more cost-effective manner."

"The total number of microorganisms that could compromise the safety of air, water, food, animals and agricultural products runs into the hundreds, so developing parallel detection tools is very important," Tiedje added.

Over the past several years, Tiedje and Hashsham have developed a lab-on-a-chip in a portable system that tests for 30 pathogens.

"The overall goal is to use these devices to target the really bad guys and to help more broadly in ecosystem management," Tiedje said. "These types of systems can be valuable in identifying diseases and infectious agents, whether in plants, animals or humans."

In the next 5 to 10 years, applications are expected in a variety of areas, including clinical diagnostics, water and food testing, produce supply chain monitoring and antibiotic resistance tracking.

Tiedje and Hashsham ultimately want to make these devices foolproof so they can be used quickly and easily by many people.

"Our goal is to emulate over-the-counter pregnancy tests, which sell for around $10, are very easy to use and have output that is easily recognizable in any language, without the need for computers or other electronic equipment," Hashsham said. "This is a very exciting time for the field."

— VAL OSOWSKI