Legacy

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The Samuel Roberts
Noble Foundation

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Volume 2, Issue 1

BREAKING THE CODE

The Noble Foundation leads an international effort to unlock the *Medicago* genome for the benefit of agriculture and humanity

Plus: On the Wings of Grace __ Learning from Experience __ Mary Jane Noble

Reinauer stands next to her waterfall.

Photograph _ *Broderick Stearns*

Cover story

Features

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On the Cover

The cover is an artistic representation of moving from the analog world of a living plant (in this case, *Medicago truncatula*) to the realm of digital information as represented by a false-color image of a DNA microarray, which allows scientists to know what genes are expressed. The ability to digitize and compare expression data for tens of thousands of genes simultaneously enables researchers to gain fundamental insight into plant growth, development and response to the environment.

Illustration _ *Scott McNeill*

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"That's what pioneers do; they find and pursue potential while the rest of us only see insurmountable obstacles."

Pioneering New Frontiers

To our readers,

Walking in Lloyd Noble's footsteps inspires a pioneering spirit.

Throughout his life, our founder exhibited the willingness to explore unfamiliar territory and seek innovative solutions. When he was only 24, he purchased his first drilling rig. He was not an oilman by trade or education, but he saw the potential of this new energy industry. Noble possessed a determination to learn the unfamiliar and the ability to reshape the standard practices in novel manners. He was an early adopter of new technologies, allowing him to drill deeper and faster than his contemporaries. In less than two decades, his drilling rigs dotted the landscape from Canada to the Gulf Coast.

Oklahoma is often cited as having two heritage industries: energy production and agriculture. Noble's influence helped fashion one, and his vision helped save the other. When Oklahoma's land was threatened by decades of poor management, he again pioneered creative methods to meet the challenge. He dedicated his own resources and created the Noble Foundation to encourage land stewardship and investigate the improvement of vital crops.

That's what pioneers do; they find and pursue potential while the rest of us only see insurmountable obstacles.

Therefore, this issue of *Legacy* highlights a variety of modern day pioneers, beginning with those who wear lab coats and explore the uncharted territory within plants. Noble Foundation scientists delve into the depths of plant DNA with the same fortitude and sense of adventure as the great explorers of the West.

For the past seven years, Noble Foundation plant scientists have worked with researchers from the United States, France and England to unravel the genome of *Medicago truncatula* (barrel medic). This simple member of the legume family holds the potential to serve as a road map to improve agriculturally significant crops, such as soybean and alfalfa. It's the first time a legume's genome has been so carefully and thoroughly examined, and the Noble Foundation's leadership on this project has received international recognition.

This issue of *Legacy* also recounts the pioneering efforts of the Noble Foundation's small grains program – it represents one of our first great achievements in plant improvement, influenced cattle operations in the southern Great Plains and continues to deliver hardier varieties to regional farmers and ranchers today.

And then there's Susie Reinauer, a pioneer woman if there ever was one. Strong and dedicated, she strives to write her own prairie story despite tremendous personal loss. The Noble Foundation is proud to stand by her side and provide agricultural assistance as she continues a journey she never thought she'd make alone.

Finally, this issue of *Legacy* honors the life of Mary Jane Noble, who passed away this fall.

Mary Jane married Lloyd Noble's son, Sam, and spent many evenings talking with her father-in-law on the front porch of his home, seeking to understand his vision. She was a woman of great foresight and few words, and she took great pride in continuing the Noble legacy. In the early 1980s, she became a member of the Board of Trustees and served for more than two decades. She was among those who worked tirelessly to shepherd the Noble Foundation from a regional organization into a global leader in plant science research and agricultural excellence. Her undeniable spirit left a lasting impression on this institution and countless individuals.

Within these pages are stories about programs and people, achievement and advancement, but, most of all, they are stories of pioneers.

Sincerely,

Michael A. Cawley
President and Chief Executive Officer

Grants

Drs. Michael Udvardi, Rujin Chen and Kirankumar Mysore received $3,831,732 in funding from the National Science Foundation (NSF) for their project entitled "Development of Genetic Resources to Dissect Gene Regulatory Networks Governing Nodule Development and Differentiation in *Medicago truncatula*." It is the largest NSF grant received by the Noble Foundation in its 62-year history.

This NSF-funded project complements earlier investments by the Noble Foundation in *M. truncatula* research (see cover story, page 8). Using data from the *M. truncatula* sequencing effort, the NSF grant will enable the Noble Foundation to understand the function of newly discovered genes, specifically genes that control the development of nitrogen-fixing root nodules of legumes.

Honored

In January 2008, the University of Oklahoma (OU) College of Medicine honored the Noble Foundation with its Distinguished Oklahoma Institution Award. The presentation came during the college's *Evening of Excellence*, an annual dinner honoring outstanding community and medical leaders in Oklahoma.

Given only to a select few organizations, the Distinguished Oklahoma Institution Award is reserved for companies or institutions which have supported excellence in medical research and established a collegial bond with the OU College of Medicine.

Snapshot

Photograph _ *Broderick Stearns*

The Noble Foundation's Administration Building stands illuminated on an early fall evening. The Noble Foundation recently completed a seven-year, $100-million campus construction project that more than doubled the organization's infrastructure. Sitting on an 800-acre campus, the Noble Foundation now has more than 500,000 square feet of research and administration space.

Letters

Congratulations on *Legacy*, the Noble Foundation's wonderful new magazine! If the first two issues are any indication, we're in for a great mix of science and features going forward. Whether it is forage grasses or mountain-biking researchers, the stories are engaging, informative and look great. Lloyd Noble would be proud to call this publication his own.

Adam Cohen
Oklahoma City

OBC Update

The Noble Foundation recently received more than $3 million to conduct research as part of the Oklahoma Bioenergy Center (OBC), the state's first coordinated biofuels initiative.

Signed into law in 2007, the OBC brings together Oklahoma's comprehensive higher education institutions – the University of Oklahoma and Oklahoma State University – with the world-class plant and agricultural research of the Noble Foundation to initiate a biofuels industry within the state. Together, the OBC institutions address the entire production value chain for biofuels – from growing bioenergy crops in the field through the biorefining process. Specifically, the OBC has divided this value chain into four key research areas: the development of crops that will fuel tomorrow's biofuels industry; crop production; harvest, collection and material transportation; and conversion.

Patience and perseverance define Kiran Mysore's life. Whether performing research in the laboratory or competing in the sports of his youth and his homeland, he approaches each endeavor with the same steadfast desire to succeed. These are the 7 facts you need to know about the scientist with a cool resolve and a fiery forehand.

1 Hailing from the state of Karnataka in southern India, Kiran moved to the United States in the early 1990s, where he earned a doctorate in genetics from Purdue University and then served as a postdoctoral fellow at Boyce Thompson Institute for Plant Research at Cornell University, Ithaca, N.Y.

2 Since 2002, the 38-year-old has led one of the Noble Foundation's research laboratories. His research focuses on molecular plant-microbe interactions, specifically looking at how plants defend against diseases.

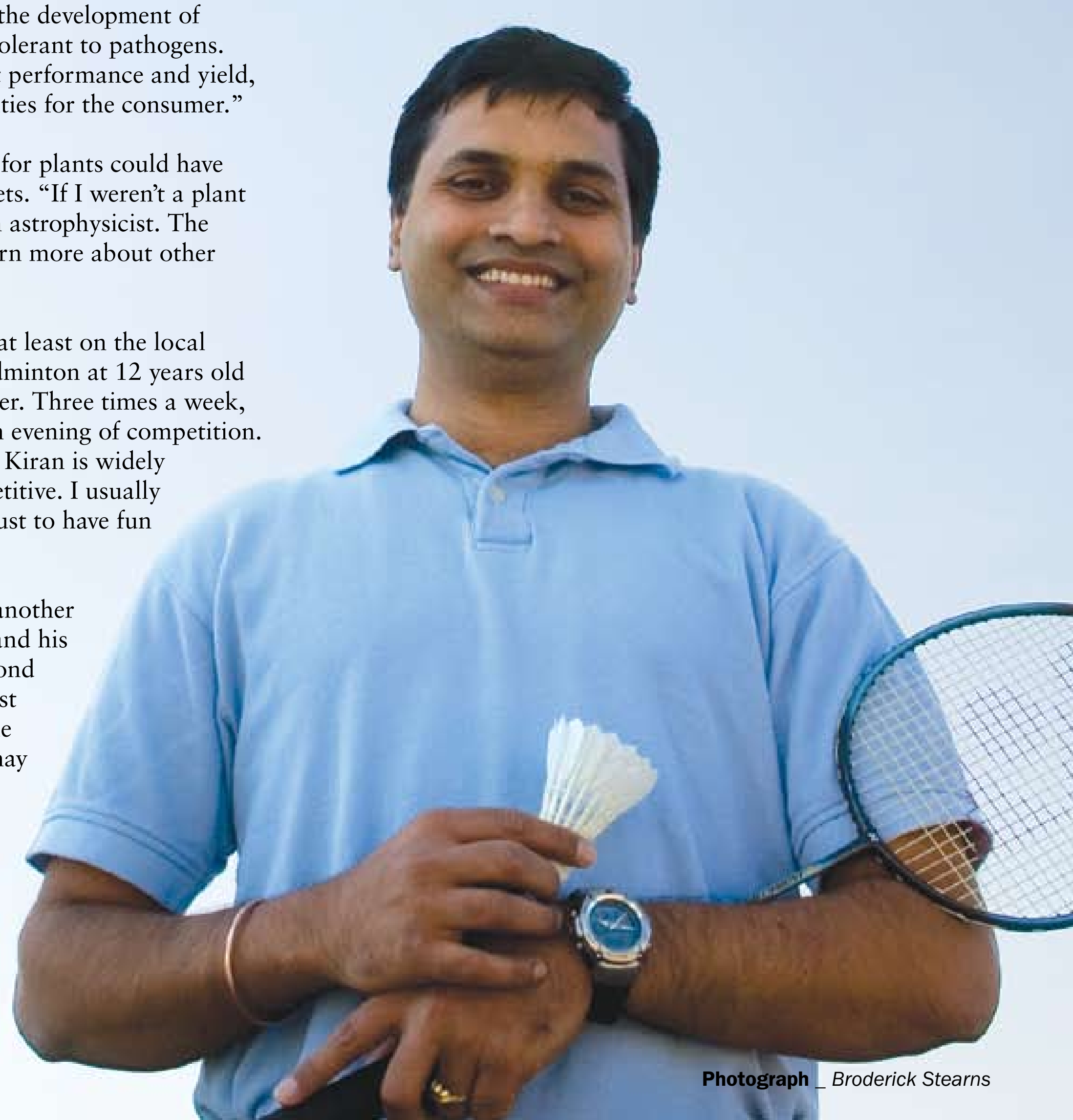
3 Kiran's research seeks solutions to devastating plant diseases, such as cotton root rot caused by a fungal pathogen found in the Southwest that affects more than 2,000 species of broadleaf plants. Kiran also continues to develop new plant science research tools, including unique ways to evaluate the function of gene candidates and improve *agrobacterium*-mediated plant transformation efficiencies.

4 The end goal of his work will be the development of engineered plants that are more tolerant to pathogens. "This, in turn, will increase plant performance and yield, resulting in reduced prices of commodities for the consumer."

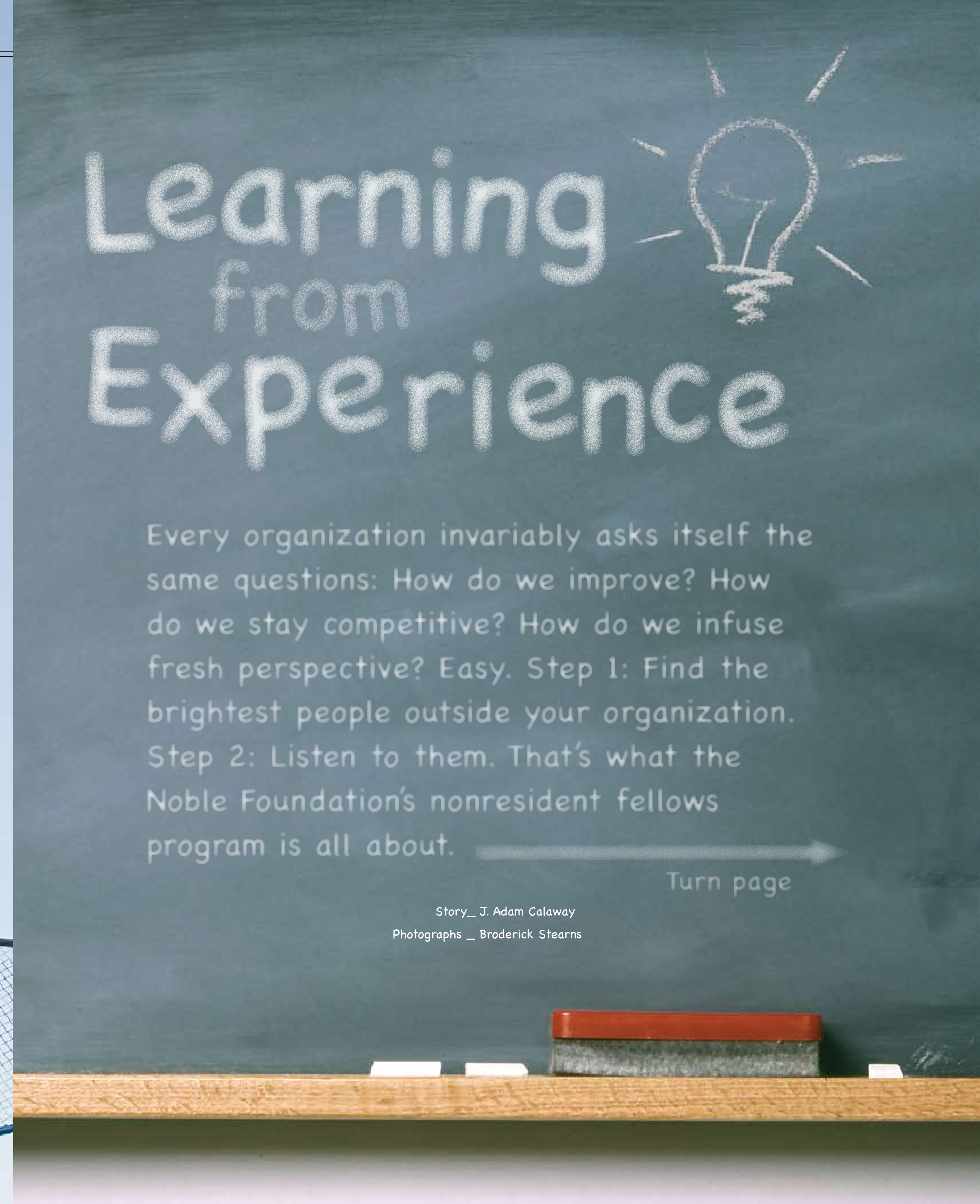
5 The associate professor's passion for plants could have very well been a passion for planets. "If I weren't a plant scientist, I would have become an astrophysicist. The universe is fascinating, and I like to learn more about other stars and planets."

6 Kiran is a star in his own right – at least on the local badminton court. He learned badminton at 12 years old by playing the sport with his father. Three times a week, Kiran now joins other employees for an evening of competition. There are teams and tournaments, and Kiran is widely considered a skilled player. "I'm competitive. I usually do pretty well, but we're mainly there just to have fun and relax."

7 In a few months, Kiran will add another member to his home team as he and his wife, Nandini, welcome their second child in April. Kiran has just one request for his unborn child, "Sleep through the night." Otherwise, a certain scientist may not be so sharp during his next game.



Photograph _ *Broderick Stearns*



Start here

David McSweeney didn't mind the avalanche of questions. In fact, he welcomed them. That was, after all, the point of this particular tour.

On a sun-kissed fall afternoon, McSweeney, a greenhouse associate with the Noble Foundation's Plant Biology Division, led four esteemed scientists through the crown jewel of the Foundation's scientific facilities – a 47,000-square-foot, technology-infused greenhouse.

With each step came another question from the scientists: "Who allots greenhouse space, and what factors play into the process?" "Who is responsible for repairs?" "What is the occupancy rate of growth chambers?" "What is the containment level?"

Each inquiry elicited a response by McSweeney – his bright New Zealand accent flavoring each word – and then another question.

The quizzing may seem demanding to the casual onlooker, but it's by design. The four scientists are members of the Noble Foundation's nonresident fellows program, which brings together an exceptional group of scientists, researchers and industry leaders from around the country to perform a candid review of the programs within each of the Noble Foundation's three operating divisions: Agricultural, Plant Biology and Forage Improvement. Their extensive critical assessments – such as this one, reviewing the greenhouse facility and its operational procedures – are pivotal to organizational improvement.

"It is easy to be lulled into complacency when you experience success; everything is going well, and you simply become content with the status quo," said Michael A. Cawley, President and Chief Executive Officer. "The nonresident fellows help maintain our momentum and set even higher standards to reach. They offer objective advice and insights, while providing outstanding counsel to our scientists, agricultural specialists and the Board of Trustees."

A fresh perspective

The Noble Foundation established the first nonresident fellows (NRF) program in the Plant Biology Division in the early 1990s just a few years after the division was formed. Subsequent NRF programs came online for the Forage Improvement and Agricultural divisions within the last 10 years. Today, each operating division benefits from a full complement of NRFs specifically tailored to assess its unique set of programs (for a complete listing, see below).

The NRFs meet with their respective divisions annually to visit with scientists or agricultural specialists, review current operations and report their findings to division directors, the President and the Board of Trustees.

"It's important to provide outside experiences and perspectives," said Douglas R. Cook, Ph.D. "You need as many different views about science as possible. Success is a result of finding the best options from various points of view."

Dennis White, Ph.D., believes the NRFs' efforts extend even further, beyond the science and the agricultural endeavors, to the individuals performing the work.

"Each NRF brings a unique set of experiences which helps us evaluate and critique," he said. "We're not just looking to build better programs, but we're helping to build stronger people in the process."

The NRF effect

The impact of the nonresident fellows program has been felt throughout each division.

During the formative years of the Plant Biology Division, NRFs suggested reorganizing the internal structure to remove a hierarchical system of report for the scientists.

"We heeded their counsel and made the change," said Richard Dixon, Senior Vice President and Plant Biology Division Director. "The results were phenomenal. Each scientist had more freedom, and the programs grew. That one change improved our science dramatically."

More recently, the NRFs have influenced the development of new scientific programs that complement the strategic direction of the Noble Foundation's research. The Plant Biology and Forage Improvement NRFs suggested expanding current plant-microbe interaction research by developing a program on endophytes. Endophytes are mutualistic fungi that live within plants, particularly grasses, and are capable of conveying pest resistance and environmental tolerances to the host plants. As a consequence, new programs within each of the divisions were initiated.

"The NRFs have been a quality sounding board," Dixon said. "They play an important role in shaping policies and helping to take a broader view of our programs. They make the tough decisions a little easier to make."

While the Plant Biology Division's NRFs have played a significant role for almost 15 years, the Noble Foundation's original division – the Agricultural Division (established in 1945) – began its NRF group in 2003.

"A healthy critique is important whether you're working on the science end or the agriculture consulting end of the Noble Foundation's efforts," said Wadell Altom, Senior Vice President and Agricultural Division Director. "We knew that a NRF group, specifically designed for our division, would bring about improvements and help facilitate changes as they needed to be made."

During the initial meetings, NRFs focused on recommendations to strengthen the division's research program.

"Their recommendations have been highly beneficial," Altom said. "Today, our research group is doing more than just supporting our consultation specialists; they are undertaking significant research to benefit tomorrow's production agriculture in the southern Great Plains."

The NRFs also worked to provide input to make the consultation program more efficient; helped plan and implement a streamlined, divisional management structure; and recently provided guidance during the completion of the business plan for the Integrity Beef Program, a comprehensive, integrated management program that assists program participants in producing consistent, high quality beef cattle intended to command increased financial returns in the marketplace.

A division is born

While playing a significant role in each division, the NRFs' greatest contribution may be helping to create a division.

In 1997, the Noble Foundation brought together a group of NRFs from around the country with the express purpose of developing a group focused on improving forages for the southern Great Plains. The plan: translate academic research into tangible, usable plant varieties. That year, the Forage Biotechnology Group was born. In 2004, the group was renamed the Forage Improvement Division.

Joe Bouton, Ph.D., from the University of Georgia, was one of the NRFs brought in to set the framework that would govern the new division.

"I had never seen an organization so willing to listen," Bouton said. "The [NRFs] gave opinions and insights, and those at the Noble Foundation responded with action. It resulted in the establishment of a complete program that enhanced the Noble Foundation's overall mission."

Eventually, Bouton went from NRF to acting director on a part-time basis and, finally, to division director.

"I had been working on the initiative for several years, so I was completely vested in its success," Bouton said. "Now, as director, I rely on the NRFs for an outside perspective, and it helps continue the success we've enjoyed. The [NRF] program continues to be one of our greatest assets."

The final piece

Creating a new division resulted in a secondary outcome – one with profound implications. The Forage Improvement Division serves as the final piece in the Noble Foundation's "pipeline," linking the efforts of the other two divisions. While Plant Biology works on fundamental scientific exploration, the Forage Improvement Division builds on that work – while conducting additional, complementary research – to create improved varieties of forages, which can then be taken into real world settings by the Agricultural Division.

"Part of the nonresident fellows program is aimed at linking the work of the various divisions," said Bill Turner, Ph.D. "We're cross-pollinating them in a way."

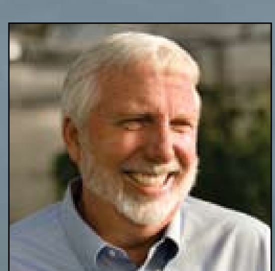
Together, the Noble Foundation's three divisions are capable of coordinating the movement of plant science discoveries from the laboratory to the field to benefit livestock, agricultural producers and consumers. This pipeline, formed by its scientific and agricultural programs, continues to be refined with the assistance of the NRFs.

"The Noble Foundation is quite the dichotomy," Turner said. "It spans the breadth of plant science, where it provides global leadership, while staying true to the mission of its founder, Lloyd Noble, through its direct consultation with regional farmers and ranchers. The NRFs are a mechanism to keep these efforts organized and on track. I only see a bright future ahead of the Foundation."

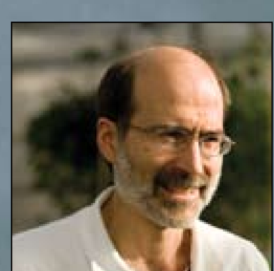
Meet the nonresident fellows

"The Noble Foundation has the whole package: a well thought-out mission, creative approaches and an unsurpassed integration of science that you will not find anywhere else. Others will mimic it, but the Noble Foundation developed it."

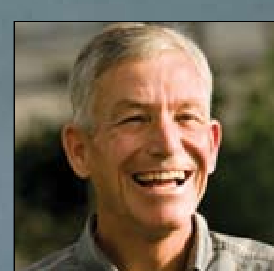
Jeffrey J. Volenec, Ph.D.
Purdue University
Forage Improvement Division



Neal Van Alfen, Ph.D.
University of California-Davis
Plant Biology Division

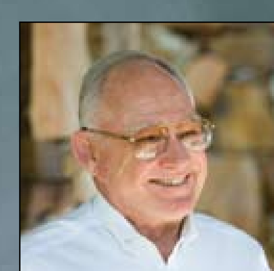


Richard Amasino, Ph.D.
University of Wisconsin-Madison
Plant Biology Division



Joe Chappell, Ph.D.
University of Kentucky
Plant Biology Division

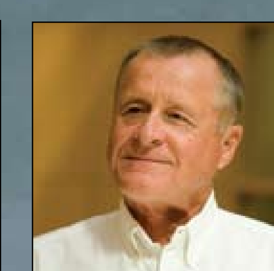
Douglas R. Cook, Ph.D.
University of California-Davis
Plant Biology Division



John Merrill, Ph.D.
XXX Ranch
Agricultural Division

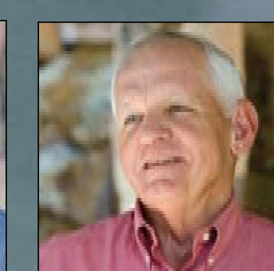
William Meyer, Ph.D.
Rutgers University
Forage Improvement Division

Mike Salisbury
Salisbury Management Co.
Agricultural Division



David Sleper, Ph.D.
University of Missouri-Columbia
Forage Improvement Division

Bill Turner, Ph.D.
Texas A&M University (retired)
Agricultural Division



Dennis White, Ph.D.
D&M Cattle Co.
Agricultural Division

BREAKING THE CODE:

For eight years, scientists at the Noble Foundation have led an international effort to unlock the *Medicago* genome and utilize it as a model plant for legume research. The results will change agriculture forever.

Story _ J. Adam Calaway
Photographs _ Broderick Stearns

Michael Udvardi collects a large latte from the apron-clad cashier at the front counter of a local coffee shop and perches on a barstool near the front picture window overlooking Ardmore's quaint downtown.

While caffeine-dispensing haunts such as this naturally induce grand discussions about the meaning of life, Udvardi and his fellow Noble Foundation principal investigator Kiran Mysore, Ph.D., are here to expound on the building blocks of life.

"Genomics is the study of all the genes in an organism," said Udvardi, Ph.D., swirling the frothy top of his drink. "In the past, genes were studied in isolation or in small groups. Now, because of new technology, we can do genomics, which looks at the entire collection of DNA in an organism. It's completely changed our perspective. It's like seeing the whole picture rather than just a few pixels in a small part of the picture."

Genomics may not be the typical coffee house conversation, but it's certainly been a hot topic amongst legume researchers worldwide since the Noble Foundation initiated what became an international effort to sequence the genome of the *Medicago truncatula* (commonly called barrel medic) and utilize it as the model species for the study of other legumes, including such agriculturally significant crops as alfalfa, soybean and peanut.

Knowledge generated from the *Medicago* genome project will allow scientists to better understand the mechanisms used by legumes for symbiotic nitrogen fixation, drought tolerance and disease resistance, and provide a blueprint for improving those traits for the benefit of humanity.

"It took tremendous vision from the Noble Foundation Board of Trustees and my scientific predecessors here to realize the importance of undertaking a project of this magnitude," Udvardi said. "It took the Noble Foundation's research in this area to the next level. It's exciting to be doing legume research at this point in time and at the place where *Medicago* genomics began."

Say that again?

Medicago truncatula is a bit of a tongue twister. Here's a little help.

To pronounce *Medicago* correctly, take "med" from "medical" and simply add "Chicago," dropping the "sh" sound.

Saying *truncatula* is even easier. Start with "trunk," but drop the "k" sound. Then pronounce the remaining syllables "catch," "you" and "la."

Now just put it together – *Med-icago trun-cat-u-la*.

The thing about alfalfa is …

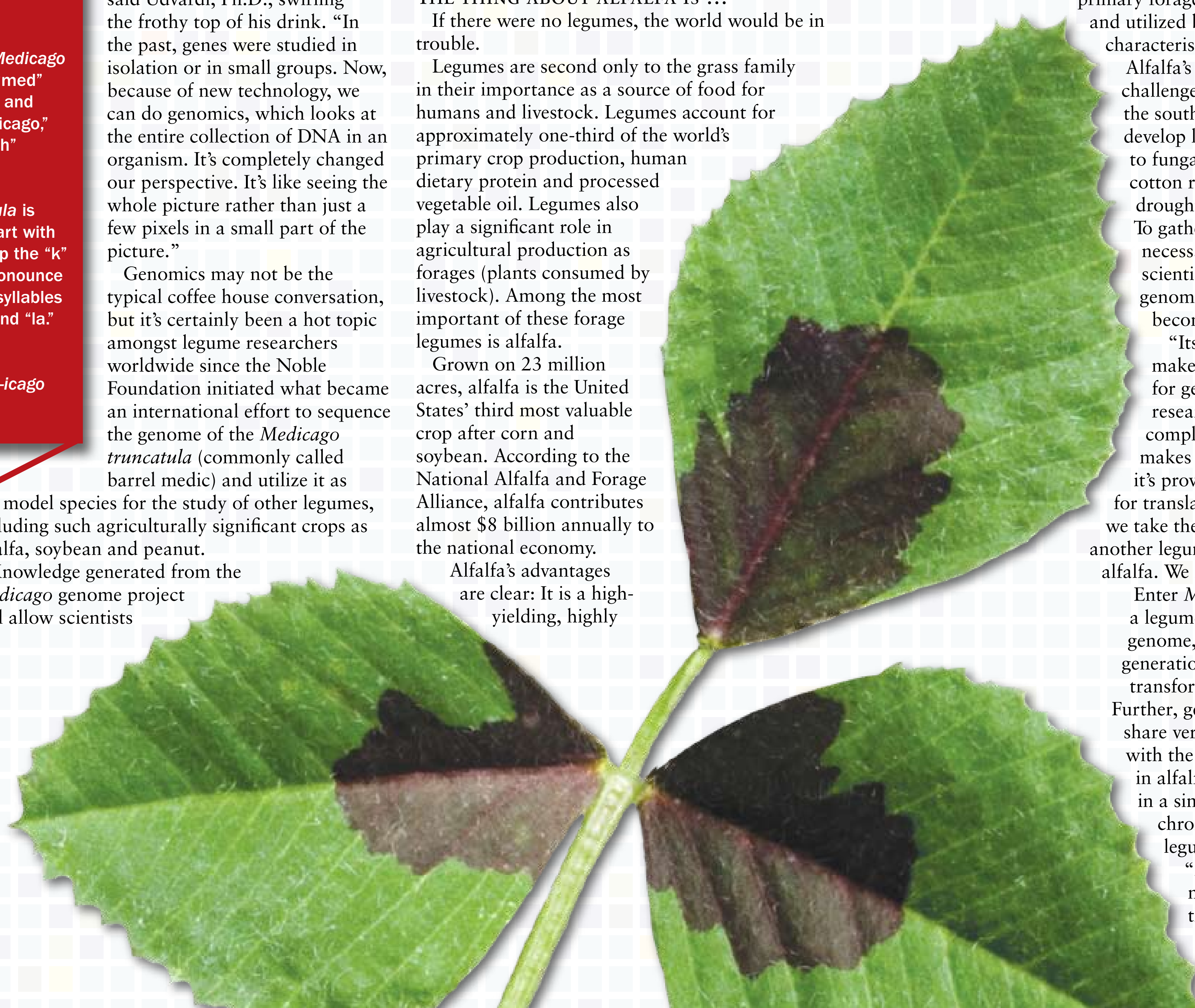
If there were no legumes, the world would be in trouble.

Legumes are second only to the grass family in their importance as a source of food for humans and livestock. Legumes account for approximately one-third of the world's primary crop production, human dietary protein and processed vegetable oil. Legumes also play a significant role in agricultural production as forages (plants consumed by livestock). Among the most important of these forage legumes is alfalfa.

Grown on 23 million acres, alfalfa is the United States' third most valuable crop after corn and soybean. According to the National Alfalfa and Forage Alliance, alfalfa contributes almost $8 billion annually to the national economy.

Alfalfa's advantages are clear: It is a high-yielding, highly nutritious perennial that is relatively tolerant of temperature extremes, salinity and drought. Most importantly, alfalfa, like all legumes, can fix its own nitrogen. Root nodules accommodate bacteria called rhizobia that convert atmospheric nitrogen (N_2) to ammonia (NH_3), which is a source of nitrogen that the plant can use for growth instead of requiring expensive nitrogen fertilizers.

"Because they fix atmospheric nitrogen so effectively, legumes like alfalfa help improve the soil for other crops and provide a significant economic advantage to farmers," Udvardi said. "The Noble Foundation highlighted alfalfa as a primary forage legume to be studied and utilized because of its valuable characteristics."



Alfalfa's not without its challenges, however. Breeders in the southern United States must develop lines of alfalfa resistant to fungal pathogens, such as cotton root rot, and tolerant of drought for dryland farming.

To gather the vital information necessary to improve alfalfa, scientists must study its genome, which is where alfalfa becomes uncooperative.

"Its large, complex genome makes alfalfa a poor species for genetics and genomics research," Udvardi said. "Its complicated genome sequence makes it inaccessible. However, it's proven to be a good target for translational genomics, where we take the work performed in another legume and apply it to alfalfa. We needed a model plant."

Enter *Medicago truncatula*: a legume with a small, simple genome, fast seed-to-seed generation time and high genetic transformation efficiency. Further, genes from *Medicago* share very high sequence identity with the corresponding genes in alfalfa and are arranged in a similar order on the chromosomes as in other legumes.

"*Medicago* is an excellent model for understanding the genetics and molecular biology of economically and agronomically important legumes with more complex genomes," Mysore said. "Still, we must build the tools and resources in a model plant and then apply them to the crop species."

The process of breaking down *Medicago* to build up alfalfa began about eight years ago with a question.

Genomics 101

You remember the building blocks of life, but don't know how they fit together? Here's a quick guide to refresh those brain cells – which, by the way, contain a complete copy of your genome.

DNA houses all the information it takes to build and maintain an organism. DNA possesses three parts: a sugar molecule, a phosphate molecule and a base, which comes in four types: adenine (A), cytosine (C), guanine (G) and thymine (T). The letters A, C, G and T represent the DNA alphabet. Each 'word' (or codon) of the DNA alphabet consists of three letters, with any combination of the four bases (such as ATG), and each 'word' translates into one of the 20 amino acids that form a linear chain of amino acids in every protein. Thus, a specific sequence of DNA encodes a specific sequence of amino acids that determine the function of the corresponding protein.

Genes reside in chromosomes and are just a small piece of the overall genome, but they're powerful because they provide instructions to make proteins within a cell. The proteins carry out most of the work in a cell and each performs a specific function. A gene (or a group of genes working together) helps determine who we are, what we look like, how our bodies work.

Chromosomes provide an organized way to package a portion of the overall genome. Each organism has a different number of chromosomes – humans (23 pairs), dogs (39 pairs) and *Medicago truncatula* (eight pairs) – each containing countless genes.

A **genome** contains all the genetic material of an organism. It is divided into chromosomes. Chromosomes contain genes, and genes are made of DNA.

Of Mice and Men … and Medicago

Senior Vice President Richard Dixon, Ph.D., has served as the Plant Biology Division Director since the division was founded two decades ago. Sitting in his office on the third story of the Plant Biology building on the Noble Foundation's Ardmore campus, Dixon leans heavily back in his chair and smiles as he recounts the seed question that began a program and helped propel the Noble ▶

Foundation onto the world's scientific stage.

"Maria Harrison, a principal investigator in the Plant Biology Division during the late 90s, first brought up the idea of using *Medicago* as a model plant," Dixon said. "She had been working on alfalfa and needed a better genetic system for her studies on beneficial root-invading fungi. She began to study it in her lab and it showed promise. We decided to invest further in developing *Medicago* as a model for our more targeted work with alfalfa. Looking back, this was the first step in an amazing journey."

In the late 1990s, Dixon and his group of principal investigators reached out to a familiar friend – Bruce Roe, Ph.D., the George Lynn Cross Research Professor in chemistry and biochemistry for the University of Oklahoma (OU). A highly regarded scientist, Roe was among an international effort that sequenced the first human chromosome (No. 22). His group concluded their research on the human genome and moved on to mice when the Noble Foundation approached him about sequencing a small portion of *Medicago*.

He agreed, taking a shotgun or random sequencing approach. The results piqued Roe's curiosity.

"We found several interesting genes," Roe said. "At the time, there was little genomics work done on plants, but then I started talking to Rick Dixon, and we discussed all the chemical compounds that a plant must produce to survive. It comes down to this: Plants can't run away. They have to survive drought and extreme temperatures. If it gets too cold or hot, we go inside and put a roof over our heads; they can't. Instead they make compounds to defend themselves, to keep themselves from being eaten by animals and to resist pathogens. Think how sick we'd be if our feet were always stuck in the mud; there are all kinds of fungi and germs. Plants have a whole plethora of disease resistance we don't have. Almost every medical drug has its heritage in plants. They make all these compounds that we don't make because we just need to make muscles to run away. We now know there are twice as many genes in plants as humans. I remember thinking: 'Wow, this is really cool!'"

Roe was sold on the sequencing project, and so was the Noble Foundation Board of Trustees. After hearing Roe's presentation about his initial findings and listening to Dixon's program objectives, the board put into place the project's cornerstone. In 2001, the Noble Foundation provided the initial grant of $5 million to the Roe-led Advanced Center for Genome Technology at OU to begin sequencing the *Medicago* genome.

"If we wanted to sequence the genome ourselves, we would have had to dedicate the entire Plant Biology Division and even more just to that," Dixon said. "It wasn't feasible for us, but Bruce's group was in place and ready to go. It took a tremendous amount of vision on the part of the Board of Trustees to see the vast potential of this work."

The Noble Foundation's substantial initial investment generated interest in the genome sequencing project at the national and international levels. The National Science Foundation contributed more than $11 million to the project, citing it as a successful example of a public-private partnership to advance science and commit important research data to the public. This project brought together major laboratories and scientists from around the world to assist in the sequencing. *Medicago*'s genome contains eight chromosomes. Roe's lab maintained the lion's share by sequencing four of the chromosomes. The remaining four were divided among laboratories at The Institute for Genomic Research (now the J. Craig Venter Institute) in Maryland, Genoscope/Centre National de Sequenage in France and Sanger Centre in the United Kingdom with support provided by national funding agencies in the United States and Europe.

While the labs began generating raw data, the Noble Foundation extended its investment, expanding necessary infrastructure on its campus and adding scientists to help develop research tools and resources (see sidebar, page 11) necessary for utilizing the information to produce tangible outcomes, as well as making it available to the global scientific community.

"The initial sequencing may have been done off campus, but the Noble Foundation has put together almost every other aspect necessary for leveraging the genome data," Dixon said. "At the time, *Arabidopsis* was the only other plant genome that had ever been sequenced, so we virtually started from scratch."

Added Roe: "Sequencers get the A, C, G and T in the correct order; the rest is up to the scientists who have to figure what gene is located where, how and why they're expressed, and what they do. That's a whole different challenge."

Function, translation and the whole crazy thing

To date, about 70 percent of the *Medicago* genome has been sequenced with roughly 40,000 genes uncovered. Despite this wealth of information, Udvardi is quick to point out: "We can see almost the entire picture, but we still don't have all the details. Just because we have the picture doesn't mean we know what we're looking at or how it works." ▶

What's genomic sequencing?

Genomic sequencing reads the DNA of a selected organism and puts it into a form scientists can study. The sequencing process uncovers the order of the nucleotide bases of a piece of DNA (represented by the letters A, C, G and T) and then uses advanced machinery and computer technology to 'stitch-together' the various pieces into a seamless whole covering an entire chromosome.

University of Oklahoma scientist Dr. Bruce Roe sequenced four chromosomes in *Medicago truncatula*. He compares sequencing to Christmas lights. "Imagine that there is an extremely long set of Christmas lights with four colors of bulbs," he said. "Our job is to figure out the order of those bulbs."

What comes after sequencing?

To assist in the study of the *Medicago* genome, the Noble Foundation has developed many genetic research tools, as well as a wealth of resources that are accessible to the international scientific community.

EST Resources

In every cell, certain genes are turned on (expressed) at any given time, while other genes remain off. Likewise, stresses, such as drought or disease, can cause genes to be expressed. Noble Foundation scientists can sequence the DNA of just the expressed genes and create a catalog of expressed sequence tags (ESTs). In collaboration with the National Center for Genomic Resources, the Noble Foundation created the *Medicago* Genome Initiative (MGI), a publicly accessible EST database incorporating all Noble-sequenced ESTs as well as all publicly available *Medicago* data available from Genbank. The database provides access to approximately 226,000 EST sequences.

Gene Expression Profiling

DNA microarrays (commonly known as "gene chips") are a collection of gene fragments arrayed on a solid surface that can be used to measure gene transcript levels via hybridization. DNA microarrays allow Noble Foundation scientists to know which genes are expressed when and where, providing insight into the developmental regulation of genes and the response of gene expression to environmental stimuli. In collaboration, The Institute for Genomic Research (now the J. Craig Venter Institute) and the Noble Foundation worked to develop a commercially available Affymetrix GeneChip.

Genetic Resources

Through various methods, Noble Foundation scientists disrupt (mutate) the genes within the *Medicago* plant, causing random mutations. Researchers then grow the plants to maturity, revealing the role of the gene in the plant and allowing scientists to study its importance. The Noble Foundation has developed mutant populations of about 100,000 plants in collaboration with Centre National de la Recherche Scientifique in France and the John Innes Centre in the U.K., which are publicly accessible to the international plant science community.

Bioinformatics

Bioinformatics refers to the use of mathematics and computer science to assist in the study of biological processes, particularly those areas that generate massive datasets. Because genomics looks at the entire genome, which in plants consists of hundreds of millions of base-pairs of DNA and tens of thousands of genes, the field of study literally would be impossible without bioinformatics. Bioinformatics is required to assemble relatively short DNA sequences into seamless stretches of DNA that cover whole chromosomes and to identify the thousands of genes on each chromosome (genomics) and to store and process quantitative data from multiple experiments for tens of thousands of gene transcripts (transcriptomics) and thousands of proteins and metabolites (proteomics and metabolomics, respectively). What would take scientists weeks, months or years to do by hand, bioinformatics can handle in minutes or hours.

Molecular Marker

Development/Mapping

Molecular markers are sequences of DNA in a chromosome, either within a gene or adjacent to one, which act like signposts signaling the presence of a gene. In traditional plant breeding, researchers cross two plants with desired traits, grow their offspring and see which ones have the traits being studied.

DNA Microarrays (gene chips)

With molecular markers, the scientists can cross two plants, check to see if the offspring have molecular markers for the trait(s) of interest at the seedling stage, and then proceed without the extensive time and money required to grow the plant and measure the target trait directly. The use of molecular markers can greatly accelerate the process of plant breeding. By maintaining a map of the markers, scientists can share information concerning the locations of genes on the various chromosomes.

Proteomics

Proteomics is the large scale analysis of proteins with the ultimate aim of describing the complete protein complement of each cell, tissue, and organ type, and the organism as a whole. Proteomic profiling reveals the actual protein constituents performing the enzymatic, regulatory and structural functions encoded by a genome at a given time. Initial profiling efforts in *Medicago* at the Noble Foundation have produced publicly-available protein profiles for stems, leaves, seedpods, roots, flowers, tissue culture cells and suspension cell cultures.

Metabolomics

Metabolites are the small molecules that characterize all cells. Many (known as primary metabolites) are involved in the generation of energy from sugars and fats, or the synthesis of the building blocks of the cell. Others (secondary metabolites) may be more specific to particular plant species and are involved in defense and interactions with the environment. Metabolites represent the non-protein end products of gene expression. Comprehensive metabolic profiling (metabolomics) offers a definitive view of the "metabolic status" of an organism, providing another tool to study gene function.

Noble Foundation scientists mine the mountain of DNA searching for genes that control functions important for agricultural production, specifically looking to improve digestibility, disease and insect resistance, and responses to abiotic stresses such as drought and soil acidity.

"Breeders have been improving plants for thousands of years, randomly selecting plants with desired traits," he said. "They were improving each generation, but they didn't know what genes they were going to get. We're identifying the genes and can now be more precise in the breeding process."

Scientists within the Noble Foundation's Plant Biology Division focus on functional genomics, which, as the name implies, seeks to understand the function of every gene in the genome.

> "We possess the ability to go from the basic science to the applied. We're a world leader in *Medicago* research, and we will continue to push the limits of this research."

"Trying to understand which genes do what in a plant is like searching through thousands of keys to find the one that unlocks the door you want to go through," Udvardi said. "And most doors require more than one key because many biological functions require the interactions of several genes."

Mysore and fellow principal investigator Rujin Chen, Ph.D., perform functional genomics by disrupting genes within the plant. Mysore and Chen utilized novel processes to inactivate genes within the DNA, causing a mutation. The mutated plants typically possess an abnormality caused by loss-of-function of a specific gene. This allows the researchers to discover a gene's role in the plant. The Noble Foundation now possesses two mutant populations of about 100,000 plants, which are publicly accessible as a living resource to benefit the international plant science community.

Udvardi's research focuses in part on gene expression. He is one of the first to use the new Affymetrix *Medicago* GeneChip® and is now building a "gene expression atlas" to catalog gene expression levels for tens of thousands of genes in all the major organ systems of the plant. This will help to decipher the roles of thousands of genes and is a resource that will be available to scientists globally.

"They are on the cutting edge of developing genetic resources," Dixon said. "Scientists from the United States to Europe, India and Japan are utilizing work done and resources generated at the Noble Foundation." (See sidebar, page 13, for a complete listing of Noble Foundation scientists assisting on the *Medicago* project.)

Functional genomics often lays the groundwork for translational genomics, which applies the discoveries in *Medicago* to other legumes. The Noble Foundation's Forage Improvement Division's legume breeders have begun the process of transferring information from *Medicago* to alfalfa, and red and white clover.

"In our purest form, this division uses molecular markers to advance our breeding populations and improve breeding processes," said Joe Bouton, Ph.D., Senior Vice President and Director of the Forage Improvement Division.

Malay Saha, Ph.D., Assistant Professor, develops molecular markers to serve as road signs to signal the presence of a desired gene. In traditional plant breeding, researchers cross two plants with different desired traits, grow their offspring and observe which offspring possess the optimal combination of desired traits. With molecular markers, the scientists cross two plants and check to see if the offspring possess the molecular marker. Having the ability to test in younger plants saves the scientists time because they do not need to field-test to see if the trait of interest is present within the plant.

Assistant Professor Maria Monteros, Ph.D., said the molecular markers vastly expedite the plant breeding process. "Instead of looking for a needle in a haystack," she explained. "It's like looking for a needle in a wheelbarrow."

Even with the advances in technology and a team of highly skilled scientists, functional and translational genomic projects require a significant investment of time to see tangible results.

"The process includes years of hurdles and hundreds of tests," Udvardi said. "Even with a model, it takes five to 10 years to develop and implement change in a plant."

Added Bouton, "If increasing yield and improving drought tolerance were easy, we would have done it 50 years ago. The genomics approach gives us a tool to explore a world previously unavailable to us."

Indeed the process of uncovering gene function and then translating it to crop species requires persistence, but Dixon sees the long-term value: "This is historically significant work, which will have major outcomes for agriculture."

INVESTING IN SCIENCE AND LIFE

Eight years ago, the Noble Foundation's $5-million sequencing grant ignited a worldwide effort to understand the *Medicago* genome and use it as a blueprint to improve other legumes. Today, the project seems to be accelerating as support continues to flow in.

During the last three years, Noble Foundation scientists have received more than $12 million from the National Science Foundation, the United States Department of Agriculture (USDA), the Department of Energy (DOE) and the state of Oklahoma to fund the study of *Medicago*-related issues from functional genomics to cotton root rot disease.

In late 2007, Udvardi, Mysore and Chen received a grant worth more than $3.8 million from the National Science Foundation (NSF) for a project aimed at understanding the function of genes that control the development of nitrogen-fixing root nodules of legumes. It is the largest NSF grant received by the Noble Foundation in its 62-year history.

"This work could have been done at a university, but the granting agency chose to fund the work at the Noble Foundation because of the major groundwork we have done in this area," Udvardi said. "We possess the ability to go from the basic science to the applied. We're a world leader in *Medicago* research, and we will continue to push the limits of this research."

The Noble Foundation team continues to set lofty goals for the *Medicago* project. Scientists hope to increase the contribution of symbiotic nitrogen fixation to benefit agriculture, modify seed composition to improve human and animal nutrition, and assist the fledgling cellulosic biofuels industry by improving plant yields and quality.

Many of the Noble Foundation scientists see the *Medicago* project as a life's work worthy of pursuit.

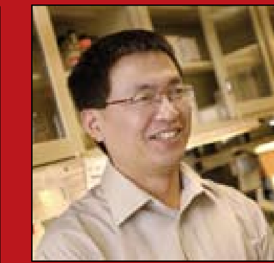
"Our work with *Medicago* will provide significant outcomes for legume research," said Udvardi, taking one last drink of his now lukewarm latte. "Since legumes play a pivotal role in global agriculture, our work holds the potential to impact farmers and ranchers worldwide."

And that's more than just coffee shop talk.

The faces behind the Noble Foundation's *Medicago* research

Elison Blancaflor
Plant Biology Division
Associate Professor
Project function: Develops cellular imaging tools

Joe Bouton
Forage Improvement Division
Senior Vice President, Division Director, Professor
Project function: Uses translational genomics to perform legume breeding



Rujin Chen
Plant Biology Division
Assistant Professor
Project function: Studies leaf development and develops genetic resources/tools

Richard Dixon
Plant Biology Division
Senior Vice President, Division Director, Professor
Project function: Uses *Medicago* genomics for gene discovery in natural products

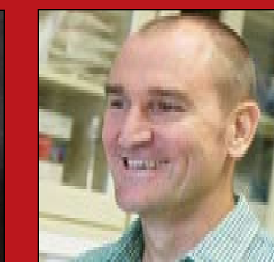
Maria Monteros
Forage Improvement Division
Assistant Professor
Project function: Develops molecular markers and uses translational genomics to enhance legume breeding

Kiran Mysore
Plant Biology Division
Associate Professor
Project function: Studies disease resistance and develops genetic resources/tools

Malay Saha
Forage Improvement Division
Assistant Professor
Project function: Develops molecular markers to expedite breeding process

Lloyd Sumner
Plant Biology Division
Associate Professor
Project function: Develops and applies proteomics and metabolomics techniques

Yuhong Tang
Plant Biology
Project function: Manages DNA sequencing and transcriptome analysis



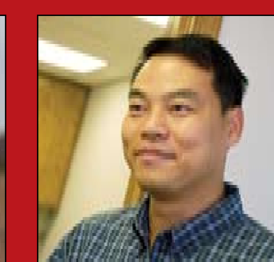
Michael Udvardi
Plant Biology Division
Professor
Project function: Develops tools for functional genomics and studies nodule function, plant nutrition, seed biology and abiotic stress tolerance

Xiaoqiang Wang
Plant Biology Division
Assistant Professor
Project function: Applies X-ray crystallography to study the structures of *Medicago* proteins

Zengyu Wang
Forage Improvement Division
Associate Professor
Project function: Develops genetic transformation methods for *Medicago* and related legumes

Jianqui Wen
Plant Biology Division
Project function: Curates and screens *Medicago* genetic resources

Carolyn Young
Forage Improvement Division
Assistant Professor
Project function: Studies fungal disease responses



Patrick Zhao
Plant Biology Division
Assistant Professor
Project function: Develops bioinformatics tools to suport legume genomics

On the Wings Of Grace

Tragedy altered Susie Reinauer's life forever, but devotion to a dream keeps her moving forward.

Story_ *J. Adam Calaway* **Photographs** _ *Broderick Stearns*

Bob and Susie Reinauer's first date should have gone like a classic romance movie. It had all the makings: a dashing former Navy flyboy turned commercial pilot, a flight attendant with a timeless beauty and a hint of moxie, and one of the most love-inspiring settings possible – the open sky. All they'd need was a touch of fate.

Instead, the Reinauer's courtship began in a dirty tan truck.

While Bob and Susie both worked for American Airlines, the reality was they never met until they were set up on a blind date, an uncertain encounter for a worldly-wise pilot.

A confident and intelligent man, Bob picked Susie up for their first date in a mid-1970s model Chevy truck, complete with hail damage, a cracked windshield and empty beer cans in the bed. It was a test, of course, to see if Susie was into pilots or into him.

"I was a little taken aback. It was a sort of bold move just to see how I would react," said Susie, smiling as she recalled the memory almost two decades later. "In reality, Bob was a humble guy, a gentleman through and through."

They were instantly inseparable, and, after nine months, the pair married. They shared everything: work, goals and strikingly similar backgrounds. Before taking to their sky-high careers, their formative years were shaped by the joys and labors of farm life. She was the oldest of five children raised on a dairy operation in Colleyville, Texas, and he was one of four Reinauer boys who grew up on the 18,000-acre ranch that was part of the famed XIT ranch in the Texas Panhandle. Their mutual adoration for the land – and the sense of freedom it offered – sparked a desire to find their own country refuge, a place where they could build their life together.

Their pursuit landed them in southern Oklahoma, then one takeoff changed everything.

Waterfalls

It's a late fall morning. Overcast skies blanket the countryside in a cool, sleepy grey. Susie sits on the edge of her sofa in her ranch-style bungalow; leather chairs, wrought iron trinkets and antler chandeliers complete the western motif. She brushes away some flaxen-colored hair from her face and continues to detail their quest to find their dream property.

The couple's criteria were strict: diverse landscape, spring-fed creek and – most importantly for Susie – a waterfall. They literally searched the nation, making stops in Wyoming, Colorado, Montana, Arkansas and Missouri. A decade passed before their local realtor brought them to 800 acres of rolling green heaven in Pontotoc County. The property seemed almost perfect, but it was not until Susie spotted a picturesque waterfall that she knew they were home.

"We stopped to have a picnic lunch by the waterfall," she explained. "As we ate, another realtor came walking by with a couple. That was it. We were out of there. I drove as fast as I could and put down the contract. Oh, Bob was mad. He was one of those guys who took his time and really thought things through, but I knew this was it."

Work began immediately. When the couple weren't in the air, they were performing every backbreaking, muscle-aching task imaginable. They hauled away tons of debris, dug holes for countless fence posts, gutted and remodeled a house and a barn, and loved every minute of it. They even cleared a field, providing Bob a runway for his other passion – antique planes.

More than two years into their farm revitalization, Susie and Bob learned about the Noble Foundation.

"We couldn't believe that this amazing resource was right here in southern Oklahoma," Susie said. "Here was this organization dedicated to helping farmers and ranchers, and it didn't charge anything for its help. It just sounded too good to be true. Bob was wary at first, because nothing's free, but his frugal side kicked in, and the opportunity to have some professional help – for free – was too good to pass up."

One phone call led to a meeting with a team of Noble Foundation agricultural specialists, who then surveyed the couple's land, provided soil testing and tailored a plan to help the Reinauers achieve their specific goals.

"We followed the recommendations as closely as possible, and I'm telling you it's the only way to go," she said. "The Noble Foundation's recommendations were the most efficient way to ranch. You need to be as efficient as possible to stay in this business. The specialists helped us solve so many problems. They gave the best advice and kept us abreast of all the latest information. They're like a private consultant except there is no fee. We never hesitated to call. They were always there for us, and they still are."

For seven years, Bob and Susie Reinauer worked their land and lived their dream.

"It's the happiest I've ever been," Susie said. "It's the happiest I've ever been."

1937 Cessna

There's no easy way to talk about Bob's death. Susie manages to tell the story with only a few restrained tears, but the pain is still obvious.

It was March 2006: Susie's crew was tending to a flight from Dallas to Washington D.C. The plan was for Bob to fly one of his antique planes into Northwest Regional Airpark to be viewed by a potential buyer. The couple was going to spend a relaxing evening with friends and then return home the next day. That was the plan.

When her flight landed, a supervisor and a friend were waiting.

"They said, 'We need to talk,'" Susie recalled, her usually cheery tone growing solemn for the first time all day. "My heart dropped. I knew the routine. Something had happened, but I didn't know what and they wouldn't tell me."

Thirty minutes passed. No explanation. When Susie's brother arrived, she still couldn't imagine ▶

Susie Reinauer stands next to her massive farm pickup in a field of fescue. Reinauer, who is one of the more than 1,400 farmers and ranchers working with the Noble Foundation, remains dedicated to her ranch despite personal tragedy.

what had happened. "He said, 'Bob had an accident, and he didn't make it,'" said Susie, pausing until she could find the right words. "The shock was unreal. I've never felt that much pain all at once. We were soul mates, and now I was all alone."

Bob took off from their home airstrip in a 1937 Cessna. A cylinder broke in the plane's 145 Warner engine causing a mechanical failure. The engine stalled, and Bob Reinauer crashed into a field less than a mile from their house.

"There's a point during any takeoff that – if there's a problem – you can't recover," she said. "That's what happened. He was an excellent pilot. There was just nothing he could do."

A few moments later, Susie stepped onto her back porch – her trio of Clumber Spaniels swarming around her knees for attention – and pointed to a grove of trees just across the road from her house. "There," she said motioning toward the southeast. "Just past those trees."

After Bob's death, Susie spent months sitting by her waterfall alone. She eventually made a decision: she wasn't leaving.

"See, all this is our plan – Bob's and mine – and I'm continuing that plan," she said. "That's what Bob would have wanted."

One big truck

At this moment, Susie is navigating one of the largest commercial trucks known to man down what could be generously called a bike path. While her 5'5" frame affords just enough height to peer over the steering wheel, she guides the behemoth truck with expert precision. She makes 90-degree turns in heavily wooded areas, branches scraping loudly on the cab. She takes steep hills methodically slow to amp up her passengers' excitement. She plays tour guide, detailing the story behind each field and valley. "This field was a mess," she says, slowing only momentarily. "It still has some spots that don't have grass, but give it another year or two and it will be perfect."

This field trip is Susie's opportunity for a little show-and-tell. It also provides her a chance to illustrate, firsthand, the Noble Foundation's impact on her operation. As she pulls up to her waterfall, she pauses for a second as though she's seeing an old friend and then talks about the severe drought that ravaged Oklahoma in the summer of 2006 just weeks after Bob's death. The Reinauers insisted throughout their search that their property enjoy a spring-fed creek. That foresight paid great dividends during the drought. Susie was able to irrigate from her creek with a little help from the Noble Foundation.

"The guys came out, measured the water flow as acre-feet available and told me how much we could use," she said. "They figured it all up, and it really helped us. The specialists at the Noble Foundation really have been there whenever I needed them. They have been incredibly supportive, and I'm appreciative for their help."

Specialists continue to work with Susie, providing direction on how to best utilize her resources, helping her select proper forages to plant and guiding her as she runs her cow-calf operation.

"Susie is one of a kind," said Hugh Aljoe, manager for the team assisting Susie. "She is determined and dedicated. She will be successful, not just because of her will, but because of her intelligence and her heart. She's working not just for herself, but for Bob."

Catfish and the future

As the morning fades into afternoon, Susie takes a quick trip down the highway to a local gas station/grill for lunch. The kind brunette, who takes her order, calls her by name, and the weathered farmers who trickle through the doors every few minutes smile when they see Susie sitting at her table. They laugh and tease her, and treat her like one of the guys.

As she nibbles at her catfish fillets, she shares thoughts about the parallels between life and agriculture.

"Sometimes you have to go down a different path," she said. "That's the way life is and agriculture is no different. There are so many variables. Things happen so unexpectedly. You have to readjust. There's always a life lesson there, you just have to be willing to see it."

Indeed, Susie sees the future, and, while it's not what she expected, she's pressing forward, embracing the memories of the man she loved while she fulfills their plan.

As lunch winds down, she talks about Bob's many antique planes. While she's sold several ("They need to continue to fly," she said. "He would have wanted them all to keep flying."), she's decided to keep Bob's favorite, a 1931 Waco F2. Only 11 remain in the world.

It's virtually a one-of-a-kind plane – much like the woman who owns it and the man it represents.

What plant science research will impact society the most in the next decade?

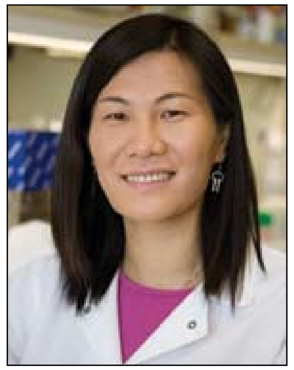
Advances in plant science improve the world around us everyday, but what about tomorrow? In this edition of *Legacy's* Q&A, four Noble Foundation scientists look ahead toward the breakthroughs that will reshape the lives of the next generation. Turns out, plants can clean the environment and fuel our cars.

Ranamalie Amarasinghe, Ph.D.
Postdoctoral Fellow
Forage Improvement Division

After a decade of genome projects, we have a large number of genes without a function assigned to them. Discovering the functions of these genes will be key to answering many questions in the future. As a society, we need hardier and better crops that can even turn into biofactories. This will only be possible if we fully understand the functions of plant genes and their regulatory networks.

Andy Hopkins, Ph.D.
Associate Professor
Forage Improvement Division

I think research on symbiosis between plants and microbes (viruses, fungi, bacteria, etc.) will impact society the most during the next 10 years. We will learn and apply new knowledge relating to the interactions between plants and the organisms they host, and how this relationship impacts traits such as nitrogen fixation, insect and disease resistance, tolerance to drought, and the nutrition of animals and humans that consume plants.



Li Tian, Ph.D.
Postdoctoral Fellow
Plant Biology Division

Basic and applied research on phytonutrients and phytoremediation will positively influence society far beyond the next decade. Phytonutrients are nutrients produced by plants that are beneficial for human health, and phytoremediation uses plants to remove pollutants from the environment. These plant science fields hold amazing potential to impact our world.

Rick Nelson, Ph.D.
Professor
Plant Biology Division

Research to improve biofuel production in the U.S. holds the greatest potential to change our lives, regardless of the outcome. Should it succeed, fuel supplies could be less volatile worldwide, and agriculture will have a huge, new product and extensive job opportunities. Without success, there will be more pressure to fully develop alternative energy sources (e.g., solar), which equals less growth for agriculture.

Small grains

Big Promise

The Noble Foundation's oldest research program continues to provide farmers new varieties of crops.

Story_ *Scott McNeill* **Photographs** _ *Broderick Stearns*

Aside from the pump jacks and drilling rigs that dot the landscape, there are perhaps no more iconic images of Oklahoma than pastures brimming with cattle and vast oceans of wheat swaying in the breeze. The latter is an image immortalized in the Rogers and Hammerstein song "Oklahoma," when they wrote, "And the wavin' wheat can sure smell sweet when the wind comes right behind the rain." It is appropriate then, that the longest running research project at the Noble Foundation involves both livestock and small grains, including wheat.

"Early in the history of the Noble Foundation, we recognized a need to have a small grain for fall and winter forage production," explained Wadell Altom, Senior Vice President and Director of the Agricultural Division. "Small grains are important in this region to meet the needs of livestock producers from mid-fall to spring when there aren't a lot of grazing options due to the dormancy of warm-season grasses."

The Noble Foundation's small grains program focuses on four primary species: rye, wheat, oat and triticale, a rye/wheat hybrid. These annual grasses are typically planted around the middle of September and, depending on the species, their life cycle is completed between April and June of the following year.

"Perennial winter grasses – those that return each year without replanting – do exist, but not many are adapted to Oklahoma," said John Guretzky, Ph.D., Research Agronomist. "The ones that are available just won't produce the quantity of forage that we need."

Joe Bouton, Ph.D, Senior Vice President and Director of the Forage Improvement Division explained the key difference between the Noble Foundation's small grains development programs and other similar programs found around the world.

"The breeding of small grains is probably the oldest agricultural project in the world. It would be hard to find a country on earth that doesn't have a breeding program – especially when it comes to wheat, rye and oats," Bouton said. "The thing that is unique about our work at the Noble Foundation is that we are not looking to increase grain production. We are looking to improve the plants for their forage qualities – better fall production, the ability to recover after grazing and better forage yields. This distinguishes our program from those found at most universities and other research centers."

Altom agrees with Bouton's evaluation of the significance of the program. "Most of the research at universities before the 1950s focused only on grain yields," he said. "Before we began our work, area farmers just planted wheat for the grain. They would occasionally use some of it for forage, but it was mainly for the grain. Our research shifted the emphasis in this region to small grains grown primarily for the forage. It changed the way that ranchers looked at grain production."

Jerry Baker, Ph.D., has a long history with small grain breeding and evaluation at the Noble Foundation. After accepting the research coordinator position in the Agricultural Division in 1990, he inherited the small grains program in 1993.

"When I came into this program, I stepped into a role to continue the work of my predecessors," Baker said. "I've always taken a lot of pride in being able to further develop the materials they gave me."

Roy Chessmore, Ph.D., also a Noble Foundation research agronomist, initiated the program in the early 1950s. He developed Elbon rye, which was released in 1956. The release of the rye variety Elbon ("Noble" spelled backwards) proved to be a landmark event for the Foundation that was then just over a decade old.

"Elbon was so successful that people used the term to refer to any improved rye – sort of like soft drinks and 'Coke,'" Altom said. "It was grown all the way to Florida. Because of it, the Noble Foundation became known near and far for its improved small grains forage program. To this day, our specialists will go to a meeting and someone will say, 'Oh, y'all are the Elbon folks.' It still has that much impact 50 years later."

Chessmore continued to breed new varieties until he left in 1965. Richard Bates, Ph.D., then ▷

took over the work and released several improved varieties during his career.

Upon assuming responsibility for the program, Bates instituted the largest and most lasting change to the small grains program.

"In the growing season of 1966-1967, Dr. Bates started a series of forage variety tests using commercially available seed," Baker said. "Two years later, he also started to include some of the experimental ryes and oats that he had developed. We have continued to add experimental lines to the tests, but the trials have been going continuously since 1966."

Variety trial reports provide production information to farmers for both forage-only production and also for forage plus end-of-season grain harvest systems. The trials have continued to test both commercially available varieties and Noble Foundation experimental varieties. The longevity of these evaluations and the critical data they provide is unparalleled.

Baker continued running the variety trials and served as the program's small grains forage breeder until his retirement in 2004.

"When Jerry Baker decided to retire, it made sense to transfer the development program to the Forage Improvement Division with their experience in plant breeding," Altom explained. "Under this arrangement, Forage Improvement develops the varieties while the Agricultural Division conducts the trials. By having a different division do the testing, you get more objectivity in the process. When they think they have something that looks promising, they hand that off to a research agronomist for the field trial. The agronomist compares the results of our varieties head-to-head against what is already commercially available."

Malay Saha, Ph.D., Assistant Professor in the Forage Improvement Division, assumed responsibility for the program's plant breeding and variety development. Although Saha's laboratory is equipped with the latest technology for genomic research, the small grains program continues as a traditional plant breeding program.

"I work to improve the small grains using the data handed down to me from my predecessors at the Noble Foundation," Saha said. "We think there is still plenty of work to be done in the short run – at least five years – advancing the work through a conventional breeding approach. Genomic techniques may play a role in the future to help us select plants with desired characteristics, but the plant breeding will probably be done traditionally. The primary goal of our breeding program is to develop cultivars with early fall-winter forage potential and grazing tolerance."

Another of the program's current breeding goals is to get rye seeds to germinate at deeper planting depths. In mid-September when rye is planted for forage, Oklahoma generally experiences high temperatures and dry conditions. If the seed is planted shallow, it can be damaged by the elements. Deeper planting would allow the seeds to get moisture from the subsoil and germinate better. The program also works to produce awnless varieties of the grains.

"Awns are the bristles at the ends of the grain, and they can be an irritant to grazing cattle," Saha said. "Eliminating them would produce a better forage."

Grass breeding is a long-term process requiring patience and years of data. Developing a new variety takes a minimum of eight to 10 years, according to Saha.

Baker confirmed Saha's time estimation saying, "The rye variety that was released in 2006, Maton II, was from a cross that Dr. Bates had made before 1993. So, in terms of breeding, you are talking about more than a decade to select, screen, test and then release the variety."

Looking back, Baker said his research in small grains was always focused on producing a better product for the farmer.

"Early in my career, I spent a short time at a university where the saying, 'publish or perish' really applied," Baker said. "That certainly has its place, but, for me, I just wanted to help farmers. I had to see a practical application. That means that sometimes you have to get out with the farmers – find out what they need. That is what is great about the Noble Foundation. It has that connection with farmers that allows the researcher to get feedback."

> "Elbon was so successful that people used the term to refer to any improved rye - sort of like soft drinks and 'Coke'."

Rye grains glisten in the evening sun. Rye is one of a handful of small grains being improved by the Noble Foundation.

How is corn reshaping livestock production?

Gone are the days when the public viewed corn as a simple side dish or movie treat. Today, this staple of American crops offers a field of dreams for those looking to produce ethanol as an alternative to traditional gasoline. And as the call for more corn-ethanol intersects concerns over rising food prices, the livestock industry finds itself changing generational processes. Below, Noble Foundation economists and livestock consultants discuss this corn conundrum, seeking to find the kernels of truth as they attempt to answer the question: "How is the cost of corn reshaping livestock production?"

Dan Childs: The price of corn impacts the livestock industry from top to bottom, but not always in the ways people think.

Deke Alkire: That's right. Every segment of the livestock production chain has been impacted. The cow-calf producers, stocker operations and the feed yards are all changing how they feed cattle.

Robert Wells: I think the best place to begin this discussion is with the expectation on the part of the American beef buyer. Consumers are accustomed to white adipose tissue, which is intramuscular fat that you see when you purchase beef. White adipose is created by feeding corn or other high carbohydrate sources for at least 60 days in the feedlot. See, the volatile fatty acids from corn are a precursor to the intramuscular fat in cattle. When cattle are grass-fed, there is less intramuscular fat and the adipose tissue is yellow. Not a lot of Americans find the yellow-colored adipose appealing.

Job Springer: Cornfed beef has always been America's niche, which worked fine when corn was $2 a bushel. Now that it's $4 a bushel or more, we see a ripple effect through the industry. Traditionally, a cow-calf operator weaned a calf, put weight on it, sent it to a feed yard for a finishing diet, which is largely made up of corn, and then it was sold. Or the producer weaned it and sent it to a stocker operator who put the weight on, and then sent it to a feed yard. Either way, corn is the largest input – up to 80-85 percent in the finishing diet – and, therefore, the most costly factor.

Childs: Even though feed yards are encouraging cow-calf producers and stocker operators to put more weight on yearlings with grass, packers want cattle to be fed a high concentrate diet for a minimum of 100 days. But now, 100 days compares to 130 to 180 days in the era of lower priced corn. The industry is currently using less corn to finish the industry's cattle. Today, with the higher priced corn, costs to add a pound in the feed yards – or cost-of-gain – have gone up from around 50¢ per pound to 80¢-90¢ per pound.

Springer: This higher cost-of-gain has caused feed yards to value heavier yearling cattle relative to the typical placement weights of 600-800 pounds. This is a signal for cow-calf producers and stocker operators to grow yearlings bigger on grass. However, higher costs of production for inputs such as fertilizer and fuel keep the lid on profits for these sectors of the beef industry.

Alkire: Corn really is the gold standard of energy feeds. If corn prices go up or down, everything else responds, which forces producers to find new and creative, economical ways to feed cattle while still satisfying the animal's nutrient requirements.

Springer: This brings us to the topic of byproduct feeds, which are animal feeds produced from the commercial processing of grain or other primary stock material. Corn is having a dual impact on the byproduct industry, which has ramifications for livestock producers.

Wells: As the demand for corn goes up, more farmers want to plant corn because of the additional monetary incentive. Since there are only so many acres of farmland capable of economically producing corn, this has to come at the expense of other crops. Combined, there were 25 percent less cotton and soybeans planted in 2007. This increased the cost of cottonseed meal and soybean meal – two major dietary protein sources typically used in many supplemental diets for cow-calf producers. In the past, protein was the most expensive nutrient in the diet, but now the cost of supplemental energy is becoming more of a concern.

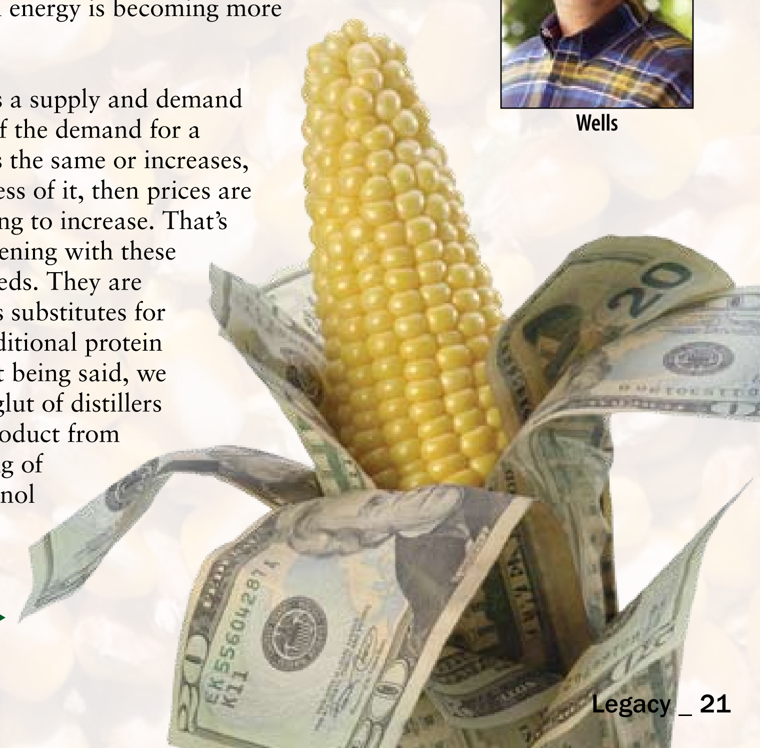
Springer: It is a supply and demand issue again. If the demand for a product stays the same or increases, but there is less of it, then prices are naturally going to increase. That's what is happening with these byproduct feeds. They are being used as substitutes for corn and traditional protein sources. That being said, we are seeing a glut of distillers grain, a byproduct from the processing of corn for ethanol production, being delivered to the market. ▶

Alkire

Childs

Springer

Wells



Wells: While this might seem like a good thing, there are concerns with distillers grains. Feeding wet distillers grains must occur close to the ethanol plants because they have a short shelf life and contain a large percentage of water. Transporting the wet distillers grains very far is cost prohibitive in addition to the logistics of being able to transport them in a timely manner. Dried distillers grains are more costly because of the energy required to remove water. Local acceptance of dried distillers grains is limited because of problems associated with handling and storage.

Alkire: This raises another issue concerning byproduct feeds – the quality of the finishing diet. Feeding a higher percentage of byproducts and less corn results in less starch in the diet. This decreases the precursors for intramuscular fat which might result in a depression in marbling scores. Researchers are currently working to identify byproduct feeding levels that will provide adequate intramuscular fat deposition and maintain the reputation of high quality American beef.

Wells: It comes down to nutrition versus profitability. Right now, livestock specialists are grappling with the maximum amount of byproducts to use. Biologically, using more byproduct feeds can cause health issues in cattle. We are attempting to come up with the correct finishing ration. In 2000, we recommended an 80 percent corn and 20 percent fiber feed. Byproducts were minimally used. Now we are commonly seeing an inclusion rate of up to 50 percent byproducts in the finishing feedlot ration. The entire industry and all the individual cow-calf operators are still adjusting, looking for the best nutritional value with the maximum profitability.

Childs: The rules have changed. When corn was cheap, we had much more flexibility at all levels of production. Now that corn has doubled in cost, the industry is stretching to reach the same quality product and still achieve a small amount of profit. The feeding sector of the industry is quite resourceful, and therefore we expect they'll get it figured out.

Wells: There's a bigger picture here. The rise in corn prices is being blamed for the rise in food costs, and that is not the complete story.

Childs: A recent report, conducted by Memphis-based Informa, says that the recent increase in corn prices only raised the price of food about 4 percent.

Wells: The USDA says for every dollar an American consumer spends on a food item, only about 19¢ goes to the farmer. That means the other 81¢ of the cost is added on after the farm. Most of it is caused by the dramatic increase in transportation costs ….

Springer: But there are also increased costs associated with labor, packaging, marketing and many other issues not associated with the livestock production. When farm inputs increase by 20 percent, the final product of a dollar item is $1.04. However, when all non-farm prices increase by 20 percent, the final product of a dollar item is $1.16.

Wells: The rising corn prices are being absorbed by the producers in the cattle industry. A little bit, but not the majority, is being passed on to the consumer. That's a major shift in current thinking about how the livestock industry has handled the corn issue.

Springer: In the end, the producers will be largely responsible for innovation within the industry. They are the ones absorbing the cost of corn, so they have to look for new ways to improve their margins. Producers must understand where they can minimize the cost-of-gain.

Alkire: That's right. We anticipate that one place producers will turn is high quality forages. It's becoming more economical to keep cattle on grass longer and to place heavier weight calves in the feedlot. As we mentioned earlier, the market has sent this signal this fall by valuing heavier weight cattle more than it has in the past.

Springer: We are telling the cow-calf producers to hold the calves longer, let them graze and then send them to the feedlots. That is a major change in thinking. It is difficult for some producers to change because they were taught one way and have been doing it that way for generations. However, those early adopters are finding out the benefits to grazing their cattle longer.

Wells: While not all of this has been sorted out, we're going to get there. One thing is for sure, though, this is not your grandpa's cattle industry.

Ken Korth takes a close look at his life's work.

A Bug's Life

Ken Korth has spent a career with the creepy crawling critters that plague agricultural crops. His research to improve insect resistance in plants has taken him to new places, but it all began at the Noble Foundation.

Story_ *J. Adam Calaway*
Photographs _ *Russell Cothren, University of Arkansas*

"… caterpillar vomit … "

The words slip casually from Ken Korth's mouth as if he were saying "good morning" to a co-worker.

Without a clarification, without even a pause, Korth, Ph.D., continues the explanation of his research unaware he had zapped his interviewer with a verbal stun gun. The conversation's momentum stalls. Korth mentally backtracks and quickly realizes why. As it turns out, this isn't the first time this particular word combination has derailed an interview.

"That's going to be in the article, isn't it?" asks Korth, already aware of the answer. "I'm used to it. It happens every time."

Such is the plight of a scientist whose research focuses on plant-insect interactions. Despite the occasional interview hiccup, Korth's work is yielding valuable insight into how plants defend against chewing insects. It's a unique field of study. One that is as intriguing as Korth's personal metamorphosis from fledgling scientist to a plant-insect principal investigator.

Korth unearthed his insect interest during his seven years at the Noble Foundation, where he served first as a postdoctoral fellow, then as senior research associate and lab manager for Dr. Richard Dixon, Senior Vice President and Plant Biology Division Director.

"The Noble Foundation shaped the direction of my research and life," Korth said. "I wouldn't be the scientist I am without the opportunities I was afforded at the Noble Foundation."

The cocoon years

Looking back, 1987 marks a significant year in the Korth timeline. He earned his bachelor's of biological sciences from the University of Nebraska that year; married Debbie, a high school classmate turned sweetheart, after graduation; and moved east to begin his doctoral ▶

> "The Noble Foundation has launched a lot of young scientists' careers because of this freedom, and mine was one of them."

studies at North Carolina State University.

Five years later, Korth graduated with his Ph.D. in genetics, a professional milestone that was easily topped a few months later by the birth of his first son, Robby. With his new family in tow, Korth moved to southern Oklahoma and the Noble Foundation in the fall of 1992.

"I was impressed by the facilities and the people. At the time, it was a relatively small group, so everybody knew everybody and that was perfect," he said. "Even though it was small then, the Noble Foundation was already recognized and respected in the plant biology world, so it was an easy decision for us to go."

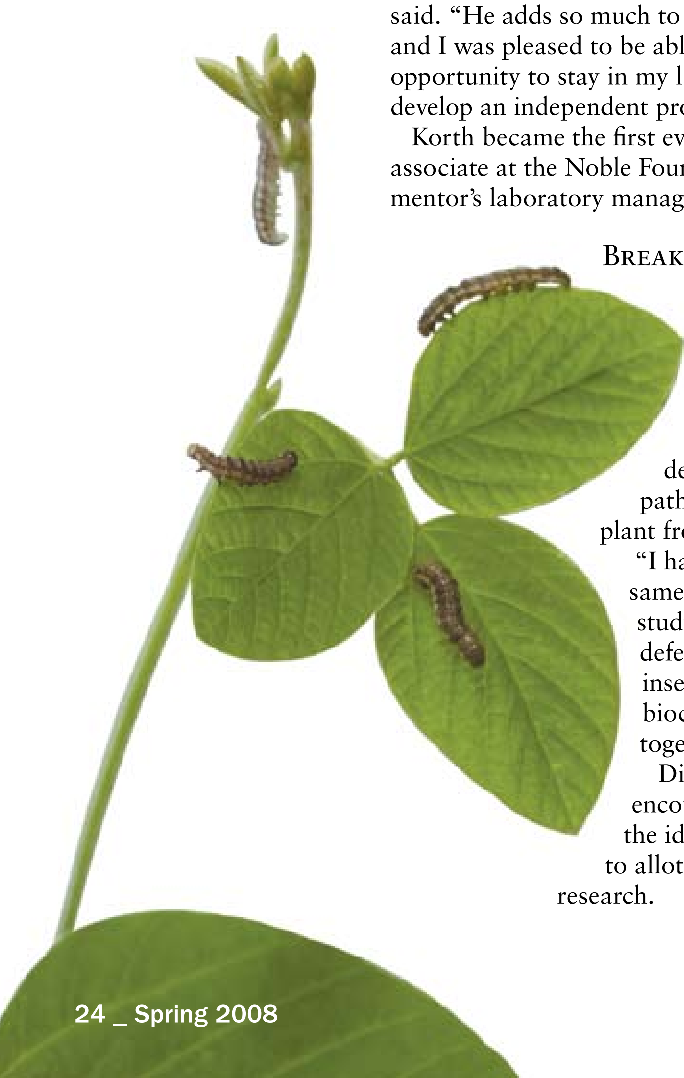
Korth's initial research focused on how defense compounds – called phytoalexins – protected potatoes against pathogens. Less than two years into his stay, Korth joined Dixon's lab and continued the research project under his tutelage.

"Rick Dixon is an expert in phytoalexins," Korth said. "I was excited to work with him. He provided mentorship, but gave me room to grow."

Korth's family was expanding as well. He and Debbie welcomed son No. 2 – Nate – in 1994, about the time he was finalizing his fellowship. Wholly content with his research and personal life, Korth asked to stay at the Noble Foundation. It was an easy decision for Dixon.

"If you talk to Dr. Korth for any length of time, it's easy to see he has an exceptional ability to ask the most pertinent scientific questions," Dixon said. "He adds so much to a research program, and I was pleased to be able to give him the opportunity to stay in my lab long enough to develop an independent program of his own."

Korth became the first ever senior research associate at the Noble Foundation and became his mentor's laboratory manager.



Breaking out

As he continued his research, Korth posed a scientific question that would literally redirect his life: Do the compounds that defend potatoes from pathogens help defend the plant from insects?

"I had the idea that the same pathways we were studying also helped defend the plant against insects," Korth said. "The biochemistry ties it all together."

Dixon not only encouraged Korth to explore the idea, but allowed him to allot half his time to the research.

"We are very fortunate here at the Noble Foundation to bring in some of the brightest and best young plant scientists in the world," Dixon said. "Bright minds create brilliant concepts, and, in Ken's case, all that was needed was some extra time for him to bring these concepts to fruition and thus become highly competitive for a permanent faculty position."

Korth credits the outlay of support as a momentous step in his professional life.

"The only reason I was able to even do this research was because Rick Dixon and the Noble Foundation foster an atmosphere where that's not only allowed, but encouraged. That is one of the things that makes the Noble Foundation unique," Korth said. "The Noble Foundation has launched a lot of young scientists' careers because of this freedom, and mine was one of them."

Taking flight

For the next four years, Korth managed Dixon's laboratory and worked as an independent scientist, shaping and directing his own research. His forays into plant-insect interaction eventually led him to the University of Arkansas, where he became the university's sole insect researcher.

"It was extremely difficult to leave," Korth said. "Personally, we had made a lot of close friends. From a work standpoint, I knew I was spoiled. From the resources to the level of professionalism, you couldn't ask for more as a scientist. But I was ready for new challenges and ready to teach. Still, it was difficult to leave behind the Foundation and the Ardmore community."

Now what about the caterpillar vomit?

Today, Korth continues to build on the work he began at the Noble Foundation. His research at the university initially focused on the production of tiny mineral crystals – called calcium oxalate – in the model legume *Medicago truncatula* (closely related to alfalfa). Korth showed how these crystals defended the plant against chewing insects.

His current research examines how plants distinguish between wounds caused by insects and non-insects. Korth said plants detect chemicals from the saliva and vomit of a caterpillar and mount a unique defense, compared to a wound caused from inanimate objects such as wind-blown matter.

"Other scientists have shown it at the biochemistry level, but we're now showing it at the gene level. It's very exciting," said Korth, who became an associate professor in 2003. "The long-term hope is to develop plants that have increased resistance against chewing insects. That means less pesticide is used, which is good for the environment and saves the farmer money."

Until then it also means Korth gets to keep saying … well, you know.

Legacy

Mary Jane Noble

1925 - 2007

As the story goes: the year was 2000 and the Noble Foundation's Board of Trustees had just agreed to assist in the construction of practice facilities for the University of Oklahoma (OU) men's and women's basketball teams when a university official made Mary Jane Noble a promise.

The official turned to the OU alumna and avid women's basketball fan and pledged that the two facilities would be equal in every way. Without hesitation, Noble replied, "As it should be. And when they're completed, I'll be there with a ruler to make sure."

Noble, 81, passed away on Oct. 26, 2007, after a lengthy illness.

"Mary Jane Noble was a warm and generous woman, who was content allowing others to talk," said Michael A. Cawley, President and Chief Executive Officer of the Noble Foundation. "However, when she spoke, it was with authority."

A longtime Ardmore resident, Noble dedicated her life to service at the local and state levels. She provided leadership for the OU Board of Regents and served as a member of the Noble Foundation Board of Trustees among countless other civic and community organizations.

Her tireless pursuit of assisting those led to her induction into the Oklahoma Hall of Fame – the highest honor an Oklahoman can receive from the state.

"She was a phenomenal woman with extraordinary vision and wisdom," said Cawley, who worked with Noble for more than two decades. "Her compassion was limitless, and she had a continual desire to give back to Oklahoma and the citizens of the state she loved."

Noble was born on Dec. 2, 1925, to Mary Bratton and Harry Curtis in Marshall, Ark. At an early age, she moved with her family first to McAlester, Okla., and then to Idabel, Okla., where she lived until entering OU. She was an intuitive learner and received her bachelor of science degree in business administration in 1946. Soon after graduation she married Sam Noble, son of legendary oilman and philanthropist Lloyd Noble who established the Noble Foundation in 1945.

While her husband continued his education, she worked as a receptionist-secretary for the Dean of Women at OU. When Sam pursued his MBA at Dartmouth College, she again worked as a secretary to help support the family. After college, the Nobles established a residence in Ardmore, and she became a homemaker and the mother of four children: Lloyd, Nick, Rusty and Shelley Dru.

Her work extended far beyond the home, however. Noble took an active leadership role in numerous organizations. She was president of Ardmore Day Nursery, the Ivy Garden Club, Sunshine Industries, Arbuckle Life Solutions and Glen Foundation of Ardmore. She was vice president of the Oklahoma Heritage Association, served on the board of directors for dozens of local charitable groups and was a member of St. Philips Episcopal Church. Noble joined the Noble Foundation Board of Trustees in 1982 beginning a tenure that lasted more than two decades.

Noble received numerous citations and commendations for her efforts. In 1983, she was honored as the Citizen of the Year in Ardmore, and in the spring of 1995, she received an honorary doctorate degree from OU – after almost 50 years of supporting higher education. The next year, Gov. Frank Keating appointed her to the OU Board of Regents, continuing a family legacy that included her father-in-law and husband. She would later chair the board from 2002-2003. Upon her death, Oklahoma Gov. Brad Henry called her "an effective and tireless advocate for education."

"She was considered a great woman by many people," Cawley said. "But she never considered herself great."

Noble remained an active OU women's basketball fan throughout her life. A season-ticket holder, she attended games during her last year even with failing health. The team honored its most faithful fan by attending her funeral, wearing their crimson and cream uniforms.

Noble would have been proud.

Aliens?

Despite its otherworldly look, this image is of an *Arabidopsis* (mustard) plant cell taken with a confocal microscope. The image shows chloroplast (red) and the plant's cytoskeleton (green fibers). Scientists at the Noble Foundation study the structure of cells to better understand how the cells function.

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