POSSIBLE
The only degree to which we have reached the end of the road of OPPORTUNITY is the degree to which we have exhausted the imaginative capacity of the human mind.”
Improving a Solution

Advanced gene editing techniques offer new hope for scientists seeking to provide farmers and ranchers with new tools that advance land stewardship.

Unlocking the Power of Legumes

Scientists gain further insight into the inner-workings of legumes in hopes of helping the plants reach their potential to advance agriculture.

From Ranch to Restaurant

A two-year national project brings together representatives from each step in the beef value chain to communicate and collectively seek progress for the first time.

No More Bare Ground

A national agricultural research initiative aims to promote soil health through the development and adoption of new cover crops across the U.S.

Serving a Greater Purpose

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More than 2.5 million people fled their homes and farms in search of better lives as a result of the drought and dust storms of the 1930s. In 1945, Lloyd Noble formed the Noble Research Institute (then known as The Samuel Roberts Noble Foundation) to provide solutions to agriculture’s greatest challenges. He knew the Southern Great Plains — and all of agriculture — would face a conveyor belt of challenges to be economic, natural or man-made. Endless trials would require ongoing solutions and a place where like-minded advocates could connect.

For 72 years, the Noble Research Institute has been a constant companion for producers, offering counsel and education. Knowledge generated in Noble’s laboratories, greenhouses and research ranches flows into the agriculture sector. Innovation and technology seek to answer questions in ways never before dreamed, making seemingly insurmountable challenges suddenly attainable.

This annual report bears witness to the legacy of a man who survived the Dust Bowl and planted a seed that has neared generations of healthier land and more productive farmers and ranchers. Within these pages are stories of men and women who are the standard-bearers of a fundamental truth that unity and boldness can shape history. They share an unflinching courage to explore, a daily devotion to rolled-up sleeves and the soil to make the impossible possible.
There will always be reasons to avoid a challenge. Maybe no one has ever attempted it before. Maybe the obstacles to success line up like an endless hurdler’s lane. How many groundbreaking ideas have died seconds after inspiration merely because of the internal roll call of self-doubt?

Within the Noble Research Institute core values exist three simple words: “Never fear challenges.” We will not let the threat of failure or the perceived size of a task deter us from venturing into the unknown. This perspective changes how we approach problems and unleashes our ability to solve them.

Throughout the pages of this annual report, we display the intrepid spirit that makes the impossible possible. Be it pioneering new CRISPR technology or leading a national cover crop initiative, we strive to attain the unattainable. This organizational ethos is not merely written on paper; it’s etched into our actions.

In the last six years, Noble has led the Soil Renaissance, which brought together experts from all corners of the soil conversation to generate new ideas and lasting solutions. Success was not assured; but we walked into the unfamiliar, and our determination resulted in the creation of the Soil Health Institute, an entity with the sole focus to safeguard and enhance the vitality and productivity of the soil.

We also helped create agricultural research organizations (AROs), a new type of 501(c)(3) that offers the next generation of philanthropists a new vehicle for using private resources to advance agriculture. And as a course of our conviction, we became the nation’s largest ARO. Noble will never fear challenges. We will continue to convene unlikely collaborators. We will seek innovations through research and technology. We will carry the banner of agriculture. This is why I am confident as we once again pioneer new territory.

In March 2017, we assembled a series of meetings with multisector stakeholders to explore and assess the potential for creating a radical new solution that would jump-start the adoption of soil health practices across the country.

The group assessed the challenges and risks of developing a new type of market, one focused on farmers and ranchers. They created lists of pros and cons, obstacles, and opportunities. The question was then posed: Could we build a large-scale program to create and sell ecosystem service credits from working agricultural lands? Walking away would have been easy. It’s always easier.

Then the words of our founder, Lloyd Noble, echoed from the past: “The only degree to which we can make real progress is the degree to which, when we have ideas, that we can get those ideas motivated into action.”

The prospect of creating a new type of market was daunting. The only missing component was the desire to try, and that is a characterisitic we are never short on. So we have embarked on an ambitious national effort to develop a market-based ecosystem services program that incentivizes farmers and ranchers to voluntarily implement soil health practices. A market such as this supports the agricultural producer with the greater goal of benefiting society at large. Healthy soil can sequester and build soil carbon, enhance water quantity and quality, increase production, and decrease the cost of inputs. And these are just a few among a long and growing list of advantages that have positive generational repercussions.

At the moment of this letter, we are in a steep-pitched obstacle and work. We know that success is not assured, but the possibility to transform agriculture is too great of an opportunity to not try.

So we will walk forward with our team. We will put forth our full effort. We will be driven by hope. Ultimately, we can be proud of the outcome because no matter the result, we never feared the challenge.

Sincerely,

For more information on the Ecosystem Services Market, visit noble.org/market.
Lloyd Noble’s vision to care for the soil and the people who depend on it continues through the organization he founded, which is now known as the Noble Research Institute in May 2017.
Great need begs for big solutions. For an inspired, well-equipped generation of people for agriculture and the world. Ideas must come from every corner of the mind to grasp the unattainable. Add a thorough plan and determination. Draw people together with a shared vision. What once seemed lofty can become reality.

Lloyd Noble established The Samuel Roberts Noble Foundation on Sept. 19, 1945, as a resource to encourage farmers and ranchers to adopt practices that would benefit the land, increase agricultural productivity, and improve quality of life. The organization, named in honor of his father, whom he described as the most charitable man he knew, became the Noble Foundation in May 2017. The Noble Foundation became known as the Noble Research Institute.

“The obligation that rests squarely on the shoulders of each generation is not what they inherit, what they have handed to them, or what they acquire from the standpoint of wealth or position, but what they do with the wealth or power that they have in their hands.”

Lloyd Noble's vision to care for the soil and the people who depend on it continues through the organization he founded, which became known as the Noble Research Institute in May 2017.
Serving a Greater Purpose
Lloyd Noble's legacy continues with a bold step for his organization and new opportunities for funding agricultural research that benefits all of society.

The prelude to a new beginning unfolded in front of nearly 400 employees on April 26, 2017. The all-employees meeting room, which had been vacant with anticipation, boomed with applause as the announcement was made: The Noble Foundation would become the Noble Research Institute in five days.

The Noble Research Institute would continue Noble's 72-year-long legacy of research, consultation and education programs. A new nonprofit, the Noble Foundation, would continue philanthropic programs.

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It Took an Act of Congress

When Steve Rhines joined the Noble Foundation, he knew they would become or start up as agricultural research organizations (AROs). The attorneys said Noble's activities ran parallel to a lesser known type of public charity: the medical research organization, or MRO, which operated more than 200,000 acres of native South Texas rangeland and research cattle ranching and wildlife conservation, the ARO structure better fit the organization.

We initiated our conversion to an ARO in September 2016. In addition to better aligning our organizational structure and charitable mission, the model strengthens our relationship with the land grant university system of Texas A&M. We are excited to see what creativity other organizations bring to the table as they become or start up as AROs. Neal Wilbourn, Ph.D., President and CEO of the East Foundation, the first 501(c)(3) agricultural research organization, their firm had helped create within the U.S. tax code in the 1950s. The difference was obvious. Medical research organizations are dedicated to human health, so the MRO model would not fit unless the definition of "medical research" could be extended to include agriculture. It could not, but another idea was planted. What if a similar new form of public charity, an agricultural research organization, or an ARO, could be created?

Pursuing the idea was not likely to be successful, the attorneys said. The pages of notes were filed away for three years, but Rhines and Noble's leadership never completely gave up on the thought.

By June 2016, Rhines, Cawley and Jeff Muen, who had joined the organization in 2013, developed a proposal to the Noble Foundation Board of Trustees. Though pursuing the ARO concept would bring many unknowns, the trio saw its potential to open up new opportunities not just for the organization but also for philanthropic giving to agricultural research on a national level.

The Board said, "Yes." Rhines and Muen spent the equivalent of several months on the road over the next seven years. They traveled the country, explaining the concept and receiving input from dozens of agricultural colleges, industry leaders, and ultimately lawmakers and their staffs. By 2015, 65 associations, universities and other nonprofits were lending their support to what had become known as the Charitable Agricultural Research Act, which had bipartisan support in both the U.S. House of Representatives and the U.S. Senate. The bill was introduced eight times from 2011 to 2015 before it was signed into law on Dec. 18, 2015, as part of the Protecting Americans from Tax Hikes Act of 2015.

The Board took a year to carefully consider how to move forward. Every piece of the organization perfectly fit an ARO, except its philanthropic giving. In December 2016, the Board unanimously decided to split the organization's plans to become an agricultural research organization, its newest form of 501(c)(3) public charity, at a special event in Oklahoma City on May 5, 2017.

Charitable man he was — his father. Beyond Noble, the availability of AROs to philanthropists addresses a greater challenge facing the U.S. agriculture industry: lack of public funding for research. AROs are a new charitable option for those, similar to Lloyd Noble, who want to dedicate their wealth to agricultural research for the public good.

"There were many times when it seemed this was going to work, but our plans would get derailed by a multitude of things that had nothing to do with the merit of the legislation," Rhines said, reflecting on the journey, in 2017. "But we kept going back to something one of the Board members, Bill Goddard, said in one of our early meetings: ‘AROs extend the legacy of Lloyd Noble. This effort serves a greater purpose’ ."
The consultation program officially formed in 1958. However, Noble employees have been working directly with farmers and ranchers since the organization’s beginnings. As early as 1946, Noble field agriculturalists advised farmers and ranchers on how to boost their soil’s productivity through fertilization and conservation practices. In 1958, consultation began with three farmers in Carter County, Oklahoma, and with three farmers in each of the seven surrounding counties. In 2017, consultants worked with 1,764 farmers and ranchers, including 88 for the first time.

RESEARCH
The Noble Research Institute focuses on research that will help farmers and ranchers improve land stewardship and productivity regionally, nationally and internationally. Scientists consider the full spectrum of agricultural research, including basic, translational and applied. They study the basic molecular and genetic levels of how plants grow and interact with the microbial world around them. They develop stronger and more efficient small grains, grasses and legumes. And they evaluate how well cattle perform in various grazing systems. In 2017, Noble scientists shared their findings through 61 peer-reviewed scientific publications.

APPLIED AGRICULTURAL SYSTEMS RESEARCH AND TECHNOLOGY
The Noble Research Institute is one of the largest agricultural producers in Oklahoma. The organization operates seven research and demonstration farms that span 14,000 acres in the southern part of the state. There, researchers raise forage-based beef cattle, grow horticultural crops like pecans, and manage natural resources in ways comparable to how farmers and ranchers in the region operate. In addition, these farms provide a place to apply research to real-world environments and an opportunity to test out practices and technologies so producers don’t have to invest their resources in trials. In 2017, 38 applied agricultural systems research and technology projects and demonstrations were initiated or in progress.

EDUCATION
Lessons learned on the farms and ranches turn into information shared with students of all ages. The Noble Research Institute hosts agricultural seminars and workshops for farmers, ranchers and others interested in hands-on agricultural production and natural resource stewardship. All are welcome to learn the latest research-based approaches to managing cattle, forages, soils, horticultural crops, natural resources and economics. The Noble Research Institute also fosters an awareness of and appreciation for agriculture in the next generation. Youth learn about science and agriculture through interactive learning opportunities including hands-on lessons, tours, field days and internships. In 2017, educational staff hosted 1,291 people on tours of Noble’s agricultural facilities as well as 1,672 farmers, ranchers and other land managers who attended 14 agricultural education events. They also reached 7,146 students and 575 teachers through tours, hands-on lessons and interactive field days.

Areas of Activity
The Noble Research Institute continues activities that had been in place before the name and structure changes. These activities are organized into four interconnected areas.

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Farmers plant cover crops, such as crimson clover, between seasons of a traditional crop, which also provide soil protection for future growth.
Wind and water carries tons of topsoil, the foundation of life, away from farmland each year. The soil, and its ability to produce food, slowly weakens. Farmers and ranchers are increasingly adopting an old-time armor for soil: cover crops. But they have many questions that still need answered.

“No civilization has outlived the usefulness of its soils. When the soil is destroyed, the nation is gone.”

Lloyd Noble | 1949
Jim Johnson, a soils and crops consultant, explains how cover crops can help improve soil health to a group of Noble Board of Directors members, most of whom are interested in the historical practice.

Today's agricultural producers are increasingly round with a practice called cover cropping. And lands? One way is to cover the soil in plants year-round with a practice called cover cropping. It started using cover crops about three years ago. I had been fighting disease and armyworms in my wheat fields, and I was getting difficult to get a good stand. I was looking for another crop to rotate with the wheat, hoping to grow more biomass for my cattle. Jim Johnson, a Noble Research Institute consultant, suggested try cover crops and helped me choose which species to plant. I've used a wide mix: brassicas, sorghum sudan, triticale, cowpeas, even okra. I use them as a cover in the summer between seasons of wheat pasture and as a mixed-species forage in rotation with the wheat every third year. I've also been experimenting for winter. There are challenges to overcome, but these two practices are helping me be more effective with my time and resources. They're benefiting the land and my ability to herd cattle.

To Develop New Cover Crop Solutions

Jimmy Emmons stumbled upon the concept of cover cropping at a farming conference about seven years ago.

The third-generation farmer and rancher from Leedey, Oklahoma, had been searching for another crop to rotate with the wheat, hoping to grow more biomass for my cattle. Jim Johnson, a Noble Research Institute consultant, suggested try cover crops and helped me choose which species to plant. I've used a wide mix: brassicas, sorghum sudan, triticale, cowpeas, even okra. I use them as a cover in the summer between seasons of wheat pasture and as a mixed-species forage in rotation with the wheat every third year. I've also been experimenting for winter. There are challenges to overcome, but these two practices are helping me be more effective with my time and resources. They're benefiting the land and my ability to herd cattle.

But Emmons found that the practice started paying off within three to four years. Today, he credits cover crops, alongside no-till and rotational grazing, with helping reduce his fuel costs by two-thirds and his fertilizer costs by half. As a result of reducing his need for inputs, Emmons has also reduced the potential for nitrogen and phosphorus runoff into nearby streams. Based on a national farmer survey funded by the U.S. Department of Agriculture, cover crop users in 2012 were planting just more than 200 million acres. By 2016, that number had doubled. Still, the estimated 17 million acres of cover crops in the U.S. today represent just a small fraction of the 250 million acres of crop fields in the U.S. as of the most recent census, from 2012.

In March 2017, the Foundation for Food and Agriculture Research and the Noble Research Institute announced a $6.6 million national research initiative to promote soil health through the development and adoption of new cover crop solutions into the hands of those who use them, or will be using them.” Butler says. 

The network of researchers will also work with farmers and ranchers to better understand what is needed in the field as well as with seed companies to expedite effective options on the market.

“Our goal is simple: to get new cover crop solutions into the hands of those who use them or will be using them,” Butler says. 

A national agricultural research initiative aims to promote soil health through the development and adoption of new cover crops across the U.S.

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Carbon is an essential element for life on Earth. It bonds with other elements to form carbohydrates, lipids, proteins and nucleic acids, which plants and animals need to survive. Carbon is found in many forms. It moves through the global carbon cycle, which encompasses the atmosphere, continents and oceans. Carbon dioxide in the atmosphere is captured by plants and microbes and turned into food through photosynthesis. Fossil fuels are ancient carbon compounds resulting from photosynthesis hundreds of millions of years ago. Burning them releases great amounts of carbon back into the air, but agriculture can help capture some of this excess by fostering plants’ ability, through photosynthesis, to store carbon in their roots and the soil.

Farmers are increasingly interested in growing cover crops. As the name suggests, cover crops “cover” ground that would otherwise lie bare. While these crops do not usually become food for us to eat, farmers can use cover crops to boost soil health, improve water quality and sequester carbon. In some cases, they can be grazed by livestock.

COVER CROP BENEFITS
When plants (and their roots) grow, generally speaking, the land is better able to retain water and the soil is less likely to be blown or washed away. Cover crops also feed the microscopic creatures that live in soil. In turn, these microbes help future crops grow healthy and strong.

Depending on the situation, cover crops can:
• Increase crop yields.
• Fix nitrogen.
• Sequester carbon.
• Reduce pollution.
• Reduce the need for herbicides.
• Attract pollinators.
• Slow or reduce erosion.
• Increase organic matter in the soil.

COVER CROP RESEARCH AT NOBLE
Farmers have many questions about which species to choose as cover crops and how to successfully implement the practice on their land. Currently, most species planted as cover crops were bred for other purposes, like forage or grain production, rather than to maximize conservation traits. The best species to plant will vary from location to location. The Noble Research Institute is part of several projects to help get new solutions into the hands of those who use or will be using cover crops:

- **Cover Crop Benefits:**
  - Control plant pests, diseases and weeds.
  - Increase biodiversity.
  - Conserve water quality.
  - Provide seasonal habitat for wildlife.

- **Developing New Cover Crop Cultivars:**
  - In 2017, the Noble Research Institute and the Foundation for Food and Agriculture Research (FFAR) launched a national research initiative made possible by a $2.2 million grant from FFAR. The initiative seeks to promote soil health through the development and adoption of new cover crops across the U.S. Species of interest include small grains (wheat, rye, oat and triticale), annual legumes (hairy vetch, winter peas and clovers) and brassicas (bumps, radishes, kale and mustards). Field studies are being conducted in Maryland, North Carolina, Oklahoma, Nebraska and Missouri.

- **Evaluating Species for the Southern Great Plains:**
  - In 2014, Jim Johnson, soils and crops consultant, began evaluating the local adaptation of a broad suite of nearly 100 common and exotic species used as cover crops. By 2017, he and partners had completed 18 site years of observation.

- **Cover Crops and Microbial Diversity:**
  - Xuefeng Ma, Ph.D., assistant professor, is developing rye, triticale and oat cultivars specifically for dual use as cover and forage. He is also developing genomic resources for small grains.
  - Suresh Bhavnani, Ph.D., assistant professor, is developing hairy vetch and crimson clover cultivars. He is also developing genomic resources for annual legumes.
  - Zengyu Wang, Ph.D., director of core research and transformation, is developing genome editing tools to identify specific genes controlling hard seed in hairy vetch.

- **The Great Cover-Crop Test:**
  - Find out more at noble.org/the-great-cover-crop-test

114%

LEGRUME CROPS WERE FOUND TO INCREASE LEVELS OF SOIL ORGANIC MATTER BY UP TO 114%
A group of industry leaders explore the story of beef production — from raising calves to selling burgers — in a new way.
The story of beef is complex. It begins with a calf born on a ranch and continues two years. Dozens of people are involved from start to finish before the story ends at dinner. Though each person depends on the others, rarely does one see the full story. Together, they seek improved sustainability.

“...the only true happiness must come from not only understanding your own needs but an understanding and willingness to secure the same things for your fellow man.”

Lloyd Noble

The no-cost consultation program was formed in 1958 to assist farmers and ranchers in applying research-based information to their operations. Consultation began with three farms in Carter County, Oklahoma, and in each of the seven surrounding counties. Consultation began with three farms in Carter County, Oklahoma, and in each of the seven surrounding counties.

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The group identified six indicators of sustain-

ability: animal health and well-being, efficiency

and yield, water resources, land resources, air

and greenhouse gas emissions, and employee

information will help her family make better breed-

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Eventually Golden State Foods will turn

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The group identified six indicators of sustain-

ability: animal health and well-being, efficiency

and yield, water resources, land resources, air

and greenhouse gas emissions, and employee

information will help her family make better breed-

ing and management decisions for the herd.

Eventually Golden State Foods will turn

omaha is where the beef cattle are raised.

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ie pause as a McDonald’s paper sack

ashes through the drives-through, fill-

ting the car with a savory aroma. Ham-

burgers are handled out, and bits are taken before

the young family journeys on to piano lessons and

ports practices.

A hamburger wrapper holds the culmination of

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A Model for Beef Sustainability

To improve the sustainability of the beef industry, all production levels must work together. Here is how the beef sustainability project will work with its partners across the U.S.

Ranchers who are part of the Integrity Beef Alliance raise the project calves from birth. The Integrity Beef program emphasizes progressive management methods, ranch stewardship and humane care of all livestock.

Integrity Beef Alliance members sell calves to Beef Marketing Group (BMG). BMG feeds and cares for the cattle in a central Kansas feedyard for about six months.

BMG sends the cattle to Tyson Foods for harvesting.

A portion of the meat goes to Golden State Foods to be incorporated into 100 percent hamburger patties. The hamburgers are sold at McDonald’s.

Making Beef Even Better

Generations of beef producers have looked for ways to do more with less. But historically, they have made progress within their own segments, or more, within the full beef value chain, which spans from the ranch to the consumer. In 2015, participants representing these various segments formed the U.S. Roundtable for Sustainable Beef. They wanted to start a conversation about how to improve sustainability—emphasizing social, economic and environmental considerations—on a larger scale in the U.S. The group has developed metrics for assessing and measuring progress in each indicator area. In February 2017, a two-year beef sustainability pilot project was launched to test these metrics in a real-world beef value chain. The project also explores scalable solutions that could be applicable to beef producers across the country and creates opportunities to share information up and down the value chain.

U.S. Roundtable for Sustainable Beef Indicators:
• Animal health and well-being
• Efficiency and yield
• Traceability
• Land resources
• Air and greenhouse gas emissions
• Employee safety and well-being

30 | NOBLE RESEARCH INSTITUTE
Plant scientists seek ways to minimize agriculture’s environ-
mental impact by studying crops, including clover, which
supply their own nitrogen needs through relationships with
soil microbes.
Plants need to eat to live. Their food commonly comes in the form of fertilizer. But the plants rarely finish their dinner. Excess washes away, wasting time and money as well as causing environmental concerns. Scientists are looking within the plants themselves to unlock their natural abilities to more efficiently use nutrients.

Plant scientists seek ways to minimize agriculture’s environmental impact by studying crops, including clover, which across their pea clans serve through relationships with soil microbes.

“Greatness can only come to any individual when they recognize that they have much to learn.”

LLOYD NOBLE

In the 1980s and 1990s, the Noble Research Institute (then the Noble Foundation) expanded into plant genetics and crop improvement research. The organization saw an opportunity to complement consultation services for farmers and ranchers by exploring the inner workings of plants and using innovative technologies to produce new crop varieties that would ultimately help farmers and all of society.

Plants need to eat to live. Their food commonly comes in the form of fertilizer. But the plants rarely finish their dinner. Excess washes away, wasting time and money as well as causing environmental concerns. Scientists are looking within the plants themselves to unlock their natural abilities to more efficiently use nutrients.
Legumes, such as this cowpea, form specialized rhizobia in the soil bacteria called rhizobia live within these nodules and provide nitrogen to the plant. Soil bacteria called rhizobia live within these nodules and provide nitrogen to the plant. Like all living creatures, the legume's blueprint for life is harbored in its DNA. Somewhere deep within its genetic blueprint are instructions for enabling it to build above-average relationships with soil microbes.

"If we can better understand what is happening at the genetic level, we will ultimately be able to improve legumes' natural abilities to efficiently acquire nutrients," says Michael Udvardi, Ph.D., chief scientific officer. Udvardi is one of two Noble researchers who, in 2017, received a four-year, $5 million grant from the National Science Foundation to continue the exploration of legumes.

"We know thousands of genes are involved in these symbiotic processes, but we don't yet know what roles most of these genes play or which ones are most important," Udvardi says. "This grant will enable us to answer these questions and contribute to advancing agriculture and reducing its environmental footprint."
Nitrogen is essential for plant growth. Nearly half of the planet’s population would face hunger without synthetic nitrogen fertilizers, according to scientist Vaclav Smil, Ph.D. However, these same fertilizers can contribute to environmental concerns when nitrogen is not captured by plants but washes away into streams. To help overcome this challenge, Noble Research Institute scientists are working to improve legumes (plants that naturally make their own nitrogen fertilizer), identify and breed plants that are more efficient nitrogen users, and develop grasses that fix nitrogen. Learn more at bit.ly/nitrogen-ag.

Phosphorus is an element essential to both plants and animals. It is one of three nutrients commonly applied to soil as fertilizer to help plants grow. It plays roles in RNA and DNA, the cell membrane, and energy transfer reactions.

The Power and Problems of Phosphorus

Most people probably don’t think about phosphorus very much during their day. Or at all. But in the next few decades, phosphorus will be on everyone’s mind. This chemical element (with the symbol P) is essential for all life as it is part of many biological molecules. P thus plays a vital role in agriculture, supporting the growth of healthy, productive crops. Unfortunately, the world is running out of P resources.

Estimates vary, but some scientists put minable phosphorus supplies at providing enough for only 30–40 more years.

9 countries control 90 percent of the world’s known phosphorus reserves.

Phosphorus is not available in nature on its own, but is found in sedimentary and magmatic deposits, mostly as mineral rock phosphate.

Unabsorbed phosphorus remains in the soil, where it becomes either tightly bound or is used by microbes. Or, through eluviation and erosion, it enters rivers, lakes and seas.

Noble Principal Investigators Wolf Scheible, Ph.D., is exploring the molecular basis of how plants can more efficiently use phosphorus.

Noble Principal Investigators Michael Iovardi, Ph.D., and Kiran Mysore, Ph.D., are studying the genes that allow legumes, like clovers and soybeans, to efficiently acquire nitrogen and phosphorus.
Plant scientists investigate possibilities for providing benefits to farmers, animals and society by improving crop varieties through an up-and-coming tool: CRISPR-Cas9.
Plant scientists see the ways agriculture can be more environmentally friendly. They have ideas for tools to help farmers and ranchers. To solve some of the planet’s most pressing problems. And now they seek to overcome a philosophical division with a new vision in plant breeding.

Plant scientists investigate possibilities for providing benefits to farmers, animals and society by improving crop varieties through an up-and-coming tool: CRISPR-Cas9.

“The only degree to which we can make real progress is the degree to which when we have ideas that we can get those ideas motivated into action.”

Lloyd Noble | 1949

In 1951, the Noble Research Institute (then known as the Noble Foundation) launched a plant-breeding program to develop new small grains varieties, including oat, rye, wheat and triticale, better suited for grazing cattle on the Southern Great Plains. In 1993, the organization became the first in Oklahoma to field-test genetically engineered crops. These crops had built-in disease resistance and other improved traits.
Improving a Solution

Advanced gene editing techniques offer new hope for scientists seeking to provide farmers with new tools that advance land stewardship.

People since the beginning of time have bred plants and animals for desirable traits. The first farmers would have propagated the largest, tastiest fruits. Even man’s best friend, the dog, has been bred for specific skills like hunting and protecting. In traditional breeding, including that of the Noble Research Institute’s 66-year-old small grains breeding program, the best plants in each generation are used as parents for the next. Perhaps the best known example of traditional selection is maize, or corn, which started out as a wild grass called teosinte more than 10,000 years ago. While ancient civilizations in Mexico and Central America developed corn, no one knew until the 20th century that DNA was the secret behind this process.

DNA is the instruction code for life. It tells living creatures how to function, and within it lies potential. Plant scientists can adjust these instructions, whether through traditional breeding or more precise methods, to produce varieties better prepared to overcome challenges faced by farmers and society at large. They can cross plants using nutrients more efficiently into growing longer or stronger in the face of drought and disease. In the 1980s and ’90s, genetically modified organisms, or GMOs, were born. Scientists have bred plants and animals for desirable traits. By 2015, about 444 million acres of GMO crops were planted across the world, GMOs, which most commonly provide insect and herbicide resistance, have been associated with yield increases and the rise in conservation tillage, according to a U.S. Department of Agriculture study. Conservation tillage practices, including no-till, help prevent erosion and other environmental degradation.

But, though the National Academy of Sciences has found “no substantiated evidence of a difference in human health risks” when comparing GMOs with conventionally bred crops, some people are uncomfortable with this type of breeding. GMOs have been subject to scrutiny and government oversight. This regulation has made it difficult and expensive to bring improved crops to market, which has limited access for smaller companies and to only a few crop classes. While traditional breeding and genetic engineering are two tools for crop improvement, and each has a starring role in Gane editing, specifically a technique called CRISPR-Cas9 is casting new light on the timeless quest to grow plants that meet societal needs.

Zengyu Wang, Ph.D., director of core research and transformation at the Noble Research Institute, is one of our most exciting new tools to help us deliver these solutions to producers for their benefit as well as that of our environment and society as a whole. 

One Step Further

CRISPR-Cas9 has gained the interest of scientists in many fields, from medicine to agriculture. In 2015, Wang decided to integrate it into his fragrance research, CRISPR stands for “clustered regularly interspaced short palindromic repeats,” and refers to a biological system based on a natural defense mechanism in bacteria. Cas9 is the associated protein. While a GMO expresses beneficial traits through a process that introduces genetic information from another species, the CRISPR-Cas9 method produces beneficial traits as the result of a precise edit made within the target species’ own DNA. Typically, when CRISPR is used to improve plants, a strand of CRISPR-Cas9-DNA and a guide RNA are inserted into the plant genome. The guide RNA directs the Cas9 protein, which acts as a pair of scissors, to accurately snip out a specified portion of the plant’s DNA. This tweak in the plant’s instruction manual enables the plant to produce a desired trait—such as drought tolerance. After adapting CRISPR in a variety of plant species, Wang and Miao Chen, Ph.D., a postdoctoral fellow, decided to try something new. Instead of inserting DNA as used in conventional CRISPR approaches, they inserted RNA. The outcome is the same except RNA, unlike DNA, does not integrate itself into the plant genome. By nature, it is a messenger that lasts only as long as it takes to deliver its instructions. This approach eliminates the need for later, additional steps, for example, backcrossing to remove inserted DNA material, before delivering field-ready, commercial plants for evaluation or use.

“Essentially, we are inducing a natural variation within the plant, comparable to what happens in the field, with much more precision, efficiency and reliability than we’ve ever had,” Wang says. Wang’s variation has proven successful in trials, and he and his team will work to apply it in agriculture’s important crop, like wheat. “Farmers and ranchers need crop varieties that will help them produce food using less soil fertilizers and pesticides,” Wang says. "CRISPR is one of our most exciting new tools to help us deliver these solutions to producers for their benefit as well as that of our environment and society as a whole."
Conventional methods of CRISPR initially insert a piece of foreign DNA to kick-start the editing process; however, the foreign DNA is segregated out in the next generation. This means the foreign DNA is not in seeds that would be sold for planting. For this reason, CRISPR-edited crop varieties will not be regulated as GMOs by the U.S. Department of Agriculture at this time.

CRISPR stands for “clustered regularly interspaced short palindromic repeats.” It refers to a system based on a naturally occurring defense mechanism in bacteria. This mechanism protects bacteria from invading viruses by enabling a scissor-like reaction that cuts and destroys the attacking virus’s DNA.

When used to edit plant genes, the system essentially snips out a specified piece of DNA within the plant while the cell seamlessly repairs the site using its natural abilities. This enables the plant to generate desirable traits.

Traditional breeding, genetic engineering (used to create genetically modified organisms, or GMOs) and gene editing (including CRISPR) are all TOOLS FOR CROP IMPROVEMENT.

A new waxy corn variety from DuPont is expected to be one of the first CRISPR-edited plant varieties on the market, sometime around 2020. Waxy corn is used in paper adhesives and food thickeners. Other potential CRISPR applications include crops that produce better yields, are resistant to diseases and pests, and better tolerate drought.

CRISPR also being used in medical research to explore ways the mechanism can help treat, and potentially cure, diseases in people.
### Financial Report at a Glance | 2017

#### Total Assets

<table>
<thead>
<tr>
<th>Asset Category</th>
<th>Amount</th>
</tr>
</thead>
<tbody>
<tr>
<td>Property and Equipment</td>
<td>$198,826,860</td>
</tr>
<tr>
<td>Grants receivable</td>
<td></td>
</tr>
<tr>
<td>Cash and prepaid expenses</td>
<td></td>
</tr>
<tr>
<td>Investments</td>
<td></td>
</tr>
<tr>
<td>Accounts receivable and other assets</td>
<td></td>
</tr>
<tr>
<td>Notes payable</td>
<td></td>
</tr>
<tr>
<td>Accounts payable and accrued expenses</td>
<td></td>
</tr>
<tr>
<td>Pension and postretirement benefits</td>
<td></td>
</tr>
</tbody>
</table>

#### Liabilities

2017 Net Assets: $167,286,365

Total Assets: $198,826,860

*As of Dec. 31, 2017*
### Statement of Financial Position (Unaudited)

**As of Dec. 31, 2017**

<table>
<thead>
<tr>
<th>Asset</th>
<th>Amount</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cash</td>
<td>$3,088,205</td>
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<tr>
<td>Investments</td>
<td>9,791,528</td>
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<tr>
<td>Accounts receivable and other assets</td>
<td>2,115,528</td>
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<tr>
<td>Grants receivable</td>
<td>52,250,000</td>
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<tr>
<td>Prepaid expenses</td>
<td>777,108</td>
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<tr>
<td>Total Assets</td>
<td>$198,826,860</td>
</tr>
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</table>

### Statement of Activities (Unaudited)

**Year Ended 2017**

<table>
<thead>
<tr>
<th>Revenue/Gain/Loss</th>
<th>Amount</th>
</tr>
</thead>
<tbody>
<tr>
<td>Interest</td>
<td>$1,069,318</td>
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<tr>
<td>Dividends</td>
<td>2,263,400</td>
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<tr>
<td>Net realized and unrealized gains on investments</td>
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<tr>
<td>Grant revenue</td>
<td>79,250,000</td>
</tr>
<tr>
<td>Other miscellaneous program and royalty income</td>
<td>6,592,208</td>
</tr>
<tr>
<td>Total Revenues, Gains and Losses</td>
<td>104,439,321</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Expense</th>
<th>Amount</th>
</tr>
</thead>
<tbody>
<tr>
<td>Operations</td>
<td>57,449,866</td>
</tr>
<tr>
<td>Grants</td>
<td>1,706,313</td>
</tr>
<tr>
<td>Management and administrative</td>
<td>5,027,350</td>
</tr>
<tr>
<td>Provision for federal excise taxes</td>
<td>361,572</td>
</tr>
<tr>
<td>Total Expenses</td>
<td>64,545,181</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Revenue/Gain/Loss in Excess of Expenses</th>
<th>Amount</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pension and post-retirement medical-related changes other than net periodic costs</td>
<td>1,992,225</td>
</tr>
</tbody>
</table>

| Change in Net Assets from Operations                                           | $41,806,365  |
The Samuel Roberts Noble Foundation, as the member/manager of the Noble Research Institute, and the employees of Noble Research Institute acknowledge and agree that the following principles apply to our association with and the activities we conduct on behalf of the Noble Research Institute:

1. The Noble Research Institute exists because of the vision and generosity of our founder, Lloyd Noble.
2. We are stewards of the resources and the vision of Lloyd Noble.
3. Our conduct will be fair and honest, and our activities will adhere to the purposes for which the Noble Research Institute was established.

Role of the Member/Manager
The Samuel Roberts Noble Foundation serves as the sole member/manager of the Noble Research Institute, LLC, an Oklahoma nonprofit single-member limited liability company.

The Samuel Roberts Noble Foundation provides the leadership for the Noble Research Institute to carry out its charitable purposes, act as a good steward of its resources, and conduct and support the activities in accordance with the vision of founder Lloyd Noble. The Samuel Roberts Noble Foundation further directs management to formulate and implement the Noble Research Institute’s strategic plan.

Corporate Documents
The organization’s current articles of organization and operating agreement can be found at noble.org/about/governance.

Annual Internal Revenue Service Informational Return
Noble Research Institute, LLC annually files a 990-PF informational return with the Internal Revenue Service. The Noble Research Institute’s current 990-PF may be downloaded at noble.org/about/governance.*

Historical returns for the Noble Research Institute are available at guidestar.org.

*The 2016 990-PF details the assets, expenditures and activities of The Samuel Roberts Noble Foundation, Inc. Noble Research Institute, LLC is the successor-by-conversion of The Samuel Roberts Noble Foundation, Inc., effective May 1, 2017.
The Nonresident Fellows program brings together a distinguished panel of scientists, researchers and industry leaders to assist the Noble Research Institute. These outside reviewers perform candid examinations of programs, offer objective advice and guidance, and provide fresh perspectives.

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Sarah Richardson
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2017 ANNUAL REPORT

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Andmore, Oklahoma
Jody Noble
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Oklahoma City, Oklahoma

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