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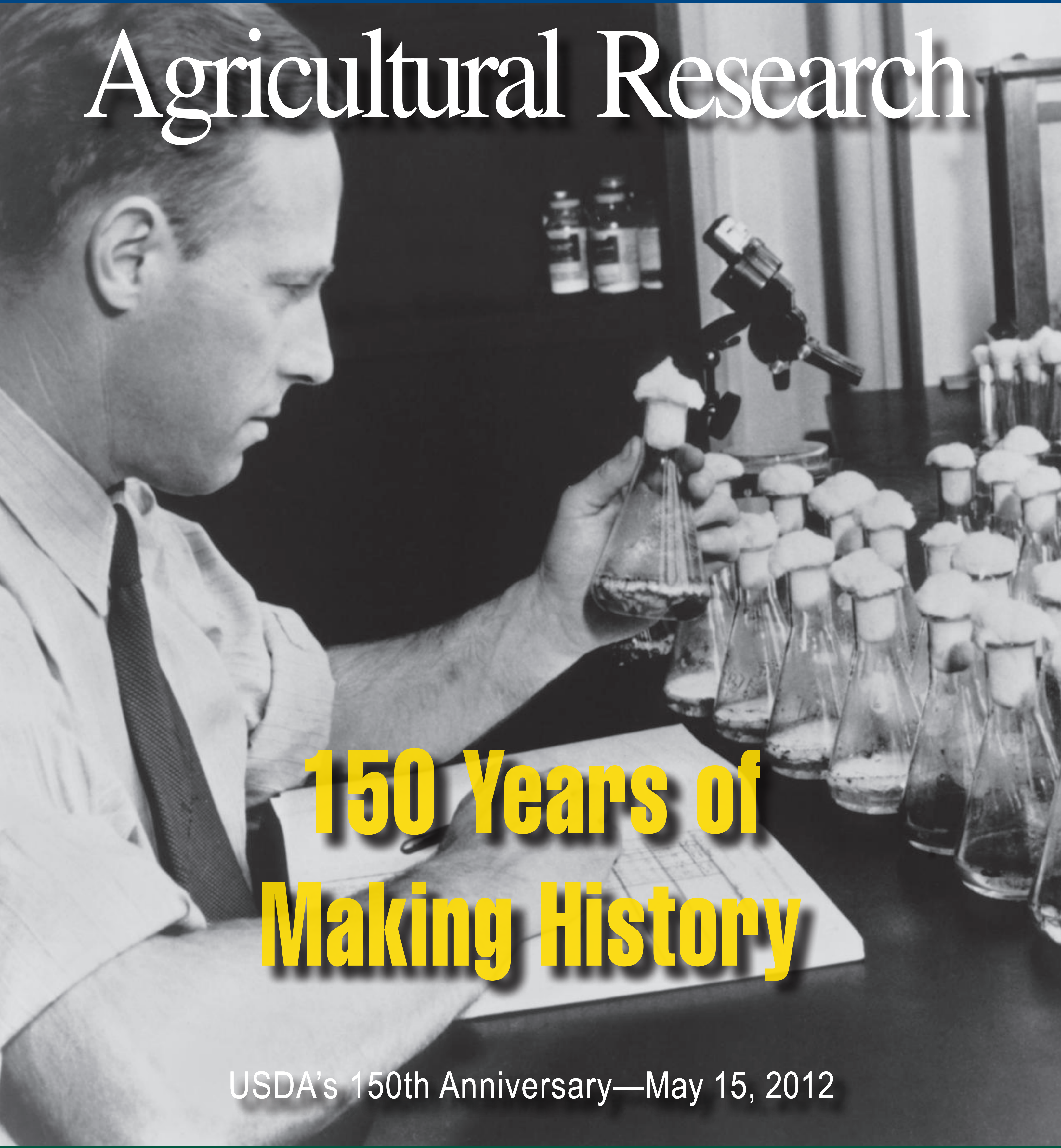
Agricultural Research



150 Years of Making History

USDA's 150th Anniversary—May 15, 2012

Agricultural Research Service • *Solving Problems for the Growing World*

FORUM

Alternative Strategies for Keeping Animals Healthy

The general public needs to know more about the importance of preventing and controlling livestock diseases and the financial impact they would have on our lives and food supply if left unchecked. Part of our mission at the USDA Agricultural Research Service is to conduct research to protect the safety of our nation's agriculture and food supply through improved disease detection, prevention, and control.

Antibiotics are recognized as one of the most important biomedical discoveries for treating infectious diseases of animals and humans. The use of antibiotics has had a major impact on increases in food-animal production and has resulted in extraordinary progress in safeguarding the health and well-being of people. Yet, while antibiotic use is critical for treating animal diseases, growing concerns about the emergence of antibiotic-resistant bacteria are leading to restrictions on antibiotic use in animal production worldwide.

A call for reduced use of antibiotics in food-animal production has heightened existing searches for new antimicrobials, but finding alternatives to antibiotics has become a main objective of the global scientific community.

ARS scientists are exploring novel technologies that can be used instead of antibiotics to help keep animals healthy. Successes include a patented method to use complex carbohydrates as prebiotics—food or feed additives that nourish beneficial bacteria inside the intestinal tract of animals—to promote gut health. Scientists at the ARS Henry A. Wallace Beltsville [Maryland] Agricultural Research Center (BARC) have also explored a method that introduces a mushroom extract, lectin, to poultry by injection into developing embryos or through drinking water, improving the birds' innate immunity against major parasitic diseases in the gut.

Scientific explorations include lessons from nature, such as various phytochemicals that show promise as antibiotic alternatives. Working with researchers around the world, BARC scientists have found that dietary supplements, such as green tea and cinnamaldehyde, can strengthen the poultry immune system. They've also developed a new antibiotic-free method that uses hyperimmune egg yolk antibodies to control intestinal poultry diseases.

Multi-drug-resistant "superbugs" are a persistent problem in modern health care, so new antimicrobials are needed. Natural antimicrobials with intimidating names like "phage endolysins" and "bacteriocins" are fairly easy to genetically modify in the lab, making them prime candidates for creating novel antimicrobials with multiple, simultaneous, and unique cell-killing, or "lytic," activities. Using this process, BARC scientists have generated a fusion protein combining parts of three antimicrobials that work together to kill *Staphylococcus*—the idea being that few bacteria could evade three simultaneous lytic activities. This fusion protein disrupts *S. aureus* more efficiently than the parent molecules, and the delivery of three unique antimicrobials in a single protein should also help prevent resistance from developing.

More research is featured in the article that begins on page 4. The studies mentioned are only a fraction of the achievements ARS scientists have made toward finding new methods to prevent and control diseases that affect animals and humans.

To explore trends globally, ARS scientists together with the World Organization for Animal Health—known as "OIE"—scientists from Europe, Asia, and the Americas; regulatory agencies; livestock producers; and the feed and pharmaceutical industries have organized a symposium on alternatives to antibiotics that will occur on September 25-28, 2012, in Paris (more information is available at alternativestoantibiotics.org). The objectives of this symposium are to highlight research and novel technologies that provide promising alternatives to antibiotics, assess challenges associated with their commercialization and use, and provide actionable strategies to support their development.

World-renown experts will look at biocontrol approaches for preventing and treating pathogens in food animals, discuss alternative host-directed strategies to enhance innate defense mechanisms in the gut, and explore new approaches that can be used as alternatives for antimicrobial growth promoters in poultry, swine, ruminant, and aquaculture production. Symposium participants representing regulatory agencies and industry will also assess challenges associated with the registration of these new technologies and provide strategies to support their development.

While ARS and other scientists continue to search for and develop viable antibiotic alternatives, it should be noted that antibiotics used in food animals today are approved as safe and effective by the U.S. Food and Drug Administration (FDA) and that animals must be healthy before entering the food chain. With careful use of approved antibiotics, producers and veterinarians continue to address disease challenges in livestock and provide us with foods derived from healthy animals.

Cyril G. Gay
ARS National Program Leader
Animal Health and Safety
Beltsville, Maryland

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Agricultural Research

Solving Problems for the Growing World

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USDA 150 YEARS 1862-2012

USDA's 150th anniversary is in 2012. Abraham Lincoln signed a bill in 1862 to create the Department. Since then, USDA scientists have been busy solving problems and creating technologies and products for people here and around the world. Story begins on page 10.

Cover: The year 2012 marks the U.S. Department of Agriculture's 150th anniversary. Agricultural scientists have been making history and improving the quality of Americans' lives ever since the Department was created on May 15, 1862. Here, in his Peoria, Illinois, laboratory, USDA scientist Andrew Moyer discovered the process for mass producing penicillin. To read about this discovery and many more, see story that begins on page 10. (K9422-1)

Strategies That Work

Alternatives to Antibiotics in Animal Health

In the early 1940s, the first antibiotic—penicillin—was used successfully to treat bacterial infections and to save thousands of lives, including those of wounded World War II soldiers. Today, antibiotics, which target microorganisms like bacteria, fungi, and parasites, are essential for human and animal health. They continue to save lives as well as increase animal production and efficiency.

However, exploration of alternative strategies to mitigate the use of antibiotics is needed in view of growing concerns about antibiotic resistance to certain strains of bacteria and increasing restrictions on their prudent use in animals. Some of the latest scientific breakthroughs and technologies, which provide new options and alternative strategies for enhancing production and improving animal health and well-being, will be presented at an international symposium, "Alternatives to Antibiotics: Challenges and Solutions in Animal Production," September 25-28, 2012, at the headquarters of the World Organization for Animal Health (known as "OIE") in Paris, France.

"A number of the new technologies have direct applications as medical interventions for human health, but the focus of the symposium is animal production, animal health, and food safety," says Cyril Gay, national program leader for animal health with the Agricultural Research Service in Beltsville, Maryland. "The result of this symposium will be an assessment of new technologies for treating and preventing diseases of animals and recommendations that will advance strategies for growth promotion and health in livestock, poultry, and aquaculture."

Over the years, ARS scientists have developed and patented new technologies that could aid in reducing antibiotic use. Some of those tools have been shown to be effective in treating mastitis in cattle, controlling foodborne enteric bacterial pathogens, creating antimicrobials that kill disease-causing bacteria, and protecting poultry against parasites.

Proven Alternatives To Fight Poultry Diseases

Avian immunologist Hyun Lillehoj, at the ARS Henry A. Wallace Beltsville [Maryland] Agricultural Research Center (BARC), has devoted her career to developing alternative-to-antibiotics strategies to control infectious diseases in poultry.

Through partnerships with industry, international scientists, and colleagues in the BARC Animal Parasitic Diseases Laboratory, Lillehoj has demonstrated the effectiveness of using food supplements and probiotics, molecules produced by cells of the immune system, and phytonutrients to fight poultry diseases like coccidiosis—a parasitic disease that causes annual losses of more than $600 million in the United States and $3.2 billion worldwide.

KEITH WELLER (K3627-16)

STEPHEN AUSMUS (D1144-4)

Left: Food supplements, probiotics, and phytonutrients have been shown to help fight some poultry diseases. Below: Left to right, avian immunologist Hyun Lillehoj and visiting scientists Duk Kyung Kim and Hong Yeong Ho identify host defense genes of broiler chickens infected with protozoan parasites.

Lillehoj is now applying similar technology to develop alternatives to treat enteric (intestinal) bacterial infections caused by *Clostridium,* a pathogen associated with necrotic enteritis in poultry.

"My work over the last 27 years at ARS has involved trying to figure out how to grow poultry without using drugs and enhance their innate immunity," Lillehoj says. "One of those strategies is genetic improvement. We've been working to identify genetic markers associated with enhanced innate immunity to enteric pathogens."

Lillehoj and her colleagues have identified several chicken genetic markers that influence parasitic diseases, and she hopes to eventually identify genetic markers for use in selecting and breeding birds for enhanced disease resistance.

The team is also studying innate immune molecules that have antimicrobial activity. During an infection, chickens respond to pathogens by producing immune molecules, some of which are antimicrobial peptides or proteins, Lillehoj explains. These tiny proteins can kill pathogens, improve host immune responses, and promote growth of beneficial gut bacterial populations.

"If we can identify all the molecules that enhance immunity, translate critical cross talks between these antimicrobial molecules and the host's immune system, and most importantly, figure out how to activate them at the proper time when birds are immature, I think we'll really have a way to use the bird's own immune system to do the job."

Lillehoj and her colleagues have identified and applied for a patent for one of the immune molecules, called "NK lysin."

"NK lysin is produced by host lymphocytes that are activated by parasites during coccidiosis infection in the gut." Lillehoj says. "We cloned the chicken NK lysin gene, made biologically active recombinant NK lysin protein, and demonstrated for the first time that this chicken recombinant antimicrobial protein (host defense molecule) not only kills chicken coccidia, but also kills *Neospora* and *Cryptosporidia*, which infect large animals and humans, respectively."

A private company is investigating to see whether chicken NK lysin can be developed into a product that targets and kills chicken intestinal parasites, she says.

Lillehoj also studies the effects of phytochemicals derived from plants such as safflower, plums, peppers, cinnamon, and green tea in enhancing the chicken's immune system. In addition, Lillehoj is partnering with commercial company leaders to examine the beneficial effects of probiotics—live, nonpathogenic bacteria that promote health and balance of the intestinal tract. (See "The Poultry Pantry: Plums, Probiotics, Safflower, and Tea," *Agricultural Research,* May/June 2009.)

Vitamin D: A Promising Treatment for Mastitis

Antibiotics are currently used to treat mastitis, the most costly and common disease of dairy cattle. But an alternative treatment may soon be available.

Scientists at the ARS National Animal Disease Center (NADC) in Ames, Iowa, have found that a natural remedy—vitamin D—can delay and reduce the severity of mastitis infection in dairy cattle.

A disease of the mammary gland, or udder, mastitis costs the U.S. economy $2 billion each year. It reduces milk production, quality, and income and can result in culling of infected cows from a herd.

"Research shows that specific levels of vitamin D need to be in the bloodstream to prevent conditions like rickets, or softening of the bones," says molecular biologist John Lippolis, in the NADC Ruminant Diseases and Immunology Research Unit. "A higher level needs to be in the blood for proper immune function. But generally, milk has very little vitamin D," which is one reason it is fortified during processing.

Lippolis and his colleagues at NADC examined the role of vitamin D in altering the response of the cow's immune system to *Streptococcus uberis,* a mastitis pathogen. They used a natural form of vitamin D, prehormone 25-hydroxyvitamin D, that's found in blood, but not in milk.

One group of cows received vitamin D by infusion directly into the infected quarter of the mammary gland, and another group received no treatment. Data was collected on feed intake, bacteria counts in milk, milk production, serum levels, and body temperature for all animals.

Animals treated with vitamin D had a significant reduction in bacterial counts and fewer clinical signs of severe infection than untreated cows. In the early phase of the infection, as vitamin D reduced the bacterial counts, milk production was greater in the treated animals than in the untreated ones.

In addition, scientists looked at bovine serum albumin (BSA) in milk and performed somatic cell counts. "BSA is a protein in blood that becomes a marker in milk to indicate when an infection gets really bad," Lippolis says. "The barrier between the milk and the blood can become a little bit degraded, indicating the

In a milking parlor at Ames, Iowa, molecular biologist John Lippolis collects milk samples for tests to see whether vitamin D reduces the severity of mastitis.

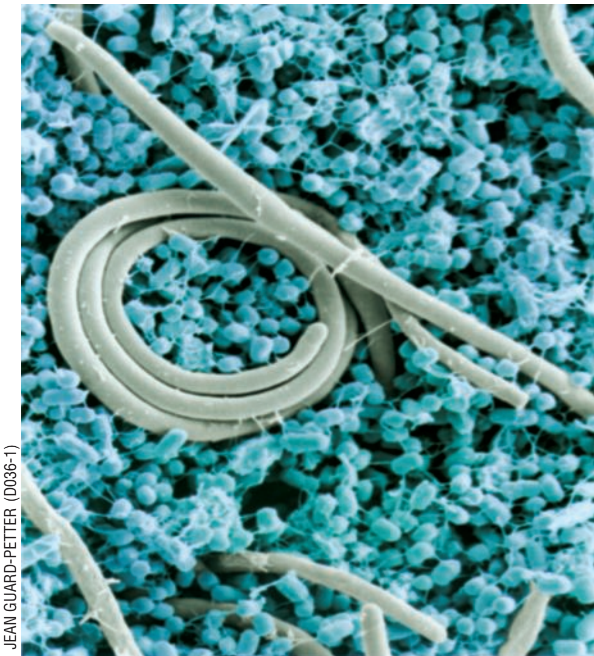
STEPHEN AUSMUS (D1189-2)

severity of the disease." Somatic cells are immune cells that enter the mammary gland to fight infection and are an important means of determining the quality of the milk.

Lippolis says findings demonstrate that vitamin D affects the immune system and suggest that it also may help reduce the use of antibiotics in treating mastitis. Vitamin D also has the potential to decrease other bacterial and viral diseases, such as respiratory tract infections, he adds.

"We hope this natural form of vitamin D will be a means to reduce antibiotic use either by using this in tandem with antibiotics and shortening the duration of antibiotic use, or as a means against some bacteria that are resistant to antibiotic treatments."

Salmonella is estimated to cause more than 1.3 million cases of human foodborne disease each year.



JEAN GUARD-PETTER (D036-1)

Effective Compounds Reduce Bacteria

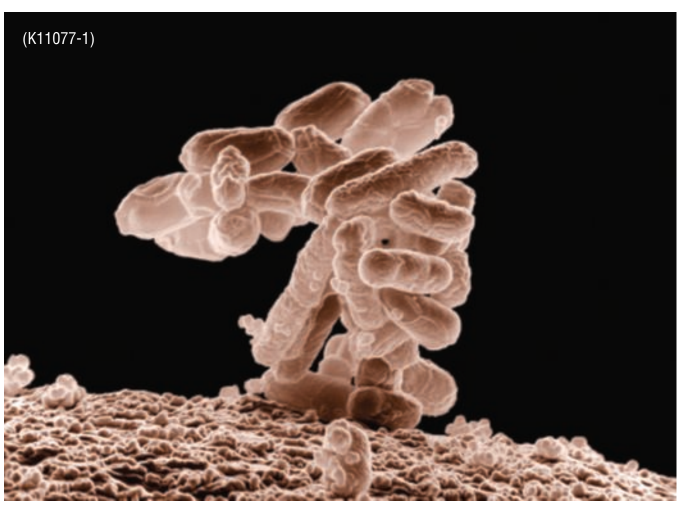
In other research, compounds proven to be effective in killing foodborne bacteria may hold potential for treating piglets and calves.

Microbiologist Robin Anderson and his colleagues at ARS's Food and Feed Safety Research Unit in College Station, Texas, received a patent for their invention, which provides a method for controlling foodborne intestinal bacterial pathogens in animals. Chlorate and a certain class of chemicals called "nitro compounds" were shown to substantially reduce or eliminate the important foodborne pathogens *Salmonella* and *Escherichia coli* O157:H7.

Salmonella is estimated to cause more than 1.3 million cases of human foodborne disease each year, costing economic losses of $2.4 billion. *Salmonella,* as well as certain *E. coli* strains, can also cause substantial losses to the swine industry due to enteric or systemic diseases of pigs.

In previous research, Anderson mixed a chlorate-based compound into water or feed and gave it to cattle 2 days before the animals were harvested. The compound, which has since been licensed by a private company, was highly effective in reducing *E. coli.* Bacterial levels fell from 100,000 *E. coli* cells per gram of fecal material to 100 cells per gram.

Scientists were equally successful in using chlorate to reduce *Salmonella* in poultry. Turkeys and broiler chickens received the compound 48 hours before they were processed. In turkeys, the incidence of *Salmonella* dropped from 35 percent to 0, and from 37 percent to 2 percent in broiler chickens.



E. coli causes significant economic losses to livestock industries. Photo by Eric Erbe, colorized by Christopher Pooley.

In a more recent study, Anderson and his team looked at using certain nitro compounds—organic compounds that contain one or more "nitro groups"—as a means of controlling foodborne bacteria. A nitro group consists of three atoms—one of nitrogen and two of oxygen—that act as one. The compound can be liquid or solid.

"We collected fresh pig feces, which harbor a mixed population of gut bacteria, and used the bacteria as a gut-simulation model to find out how the nitro compounds would work," Anderson says.

Salmonella or *E. coli* were treated with or without chlorate and with or without an appropriate amount of nitro compound. At various intervals, data was collected on the number of bacteria to determine the treatment's effect on pathogen survivability.

"We found that chlorate by itself had significant bacteria-killing activity against *E. coli* and *Salmonella,* and that activity was enhanced 10- to 100-fold with addition of the nitro compound," Anderson says. "We also found that the nitro compounds by themselves had significant bacteria-killing activity, and that activity was more persistent than the chlorate activity by itself."

The nitro and chlorate compounds together were the best treatment. "The two compounds were synergistic," Anderson says. "They worked well together by enhancing the efficacy of the other."

Scientists hypothesize that this method could have applications for young animals that have been recently weaned and are particularly susceptible to bacterial infections.

"This could be used instead of certain antibiotics that are commonly used to treat diarrheal infections in young pigs and cattle," Anderson says.

Designing Antimicrobials To Destroy Bacteria

Creating targeted antimicrobials is the focus of David Donovan, a molecular biologist in BARC's

Animal Biosciences and Biotechnology Laboratory. Research conducted by Donovan, in collaboration with university, industry, and federal scientists, has demonstrated that phages—viruses that infect bacteria—produce enzymes that can be used to kill pathogens like methicillin-resistant *Staphylococcus aureus*.

"These enzymes—known as 'endolysins'—have molecular domains that can be isolated and will act independently of their protein surroundings," Donovan says. "They can be shuffled like cars in a train, resulting in an antimicrobial that targets just the pathogens of interest, significantly reducing the odds that nontargeted bacteria will develop resistance."

Endolysins destroy bacteria by breaking down their cell walls, he explains. Antimicrobials are created by joining key domains from multiple cell-wall-degrading endolysins. The novel enzymes have been successful in killing streptococci and *S. aureus*.

Addressing Animal Health

As the demand for animal food products increases to meet the nutritional needs of a growing world population, finding alternative strategies to prevent and control animal diseases has become a global issue and a critical component of efforts to alleviate poverty and world hunger, Gay says.

This year's symposium will provide an opportunity for an international community of scientists, veterinarians, and public policymakers to learn more about the pros and cons of using alternative biotherapeutics to reduce bacterial pathogens associated with food animals, he says.

"The major issue to be addressed is novel biocontrol approaches for reducing bacterial pathogens in food animal production that employ strategies specifically geared to reduce or eliminate drug-resistance development," Gay says.

More information about the September symposium is available at www.alternativestoantibiotics.org.—By **Sandra Avant,** ARS.

This research is part of Animal Health (#103), Food Animal Production (#101), and Food Safety (#108), three ARS national programs described at www.nps.ars.usda.gov.

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PEGGY GREB (K11670-2)

Nitro and chlorate compounds may be used in the future to kill disease-causing bacteria in the gut of calves and other young livestock.

Animals that have recently been weaned are particularly susceptible to bacterial infections and may benefit a lot from the nitro and chlorate treatments.

KEITH WELLER (K7975-10)

BRADLEY KING (D2495-1)

A half-circle spinning spray-plate sprinkler being evaluated on a potato research plot.

New Insights Into Irrigation Management

Pacific Northwest potato and sugar beet farmers who irrigate their crops with sprinklers need to know a lot more than when to turn on the faucet. The region's powdery silt loam soils don't contain much stabilizing organic matter, and existing soil aggregates that facilitate water infiltration can be broken up during irrigation. Afterwards, the loose particles of sand, silt, and clay that remain can dry to form a solid crust that greatly limits infiltration into the soil.

This means that growers not only need to calculate how much water should be supplied during irrigation, but they also need to ensure that the kinetic energy transferred from each water droplet to the soil surface during irrigation doesn't contribute to the breakup of the fragile soil aggregates. They also need to develop irrigation protocols that won't saturate soils or erode valuable topsoil.

Agricultural Research Service soil scientist Gary Lehrsch has been studying sprinkler irrigation for more than a decade. He has used his findings to develop numerous irrigation guidelines to protect soil structure, maintain soil quality, sustain soil resources, and increase the odds that water delivered via sprinkler irrigation will reach the root zones of growing crops.

"Sprinkler heads on center-pivot irrigation systems can be inexpensively and easily modified to adjust the water volume applied per pass and the force with which the water droplets hit the soil surface," Lehrsch says. He works at the ARS Northwest Irrigation and Soils Research Laboratory in Kimberly, Idaho.

In one 5-year investigation, Lehrsch and colleagues evaluated the effect of sprinkler-droplet kinetic energy on soil crust strength and aggregate stability. They irrigated sugar beet plots using a 500-foot, four-span, lateral-move sprinkler system equipped with sprinkler heads that were positioned 6 feet above the soil.

The sprinkler heads were modified so that irrigations had either low or high droplet energies. The scientists included test plots with nylon covers, which ensured that when those plots were irrigated, the energy in the droplets would be absorbed by the netting and not the soil surface.

After the sugar beets were planted, the plots were irrigated with 0.6 inches of water at an average rate of 1.5 inches per hour two to four times per week for 5 weeks after planting. The team measured surface-soil penetration resistance—which indicates the strength of the soil crust—about 4 days after the first postplant irrigation and 14 days after the last irrigation.

Water Worries

Lehrsch and colleagues found that aggregate stability decreased from 66 percent to 55 percent when the irrigation's droplet energy increased from 0 percent (in the test plot with the nylon netting) to the lowest rate under investigation. Sugar beet seedling emergence increased 6.4 percent when droplet energy was reduced

Subsurface compaction can be tested by measuring soil penetration resistance with a penetrologger.

JAMES FOERSTER (D2497-1)

A geotester used to measure the strength of soil crust.

NWISRL (D2499-1)

50 percent from the highest rate studied, an emergence increase that could raise net income for southern Idaho sugar beet growers by nearly $6.2 million every year.

"We've concluded that these droplet-energy restrictions should be in place until sugar beet seedlings have emerged and become established," Lehrsch says. "After that, sprinklers can be reconfigured to apply greater water volumes—at necessarily greater levels of energy—for the rest of the growing season."

The researchers also observed that after multiple irrigations, soil penetration resistance decreased as droplet size and energy increased, probably because the larger droplets hit the ground with enough force to loosen soil particles and erode surface soil. They saw evidence of this erosion process during late-season irrigations when sediment-laden runoff flowed from row hills into nearby furrows and basins.

Lehrsch recommends keeping crop residues on the surface to check erosion and amending soils with organic materials such as manure or whey—the liquid byproduct remaining after cheese is made—to bolster soil-aggregate stability. These recommendations are based in part on his research that showed adding whey to furrows before irrigation increased soil-aggregate stability 25 percent at the 0- to 0.5-inch depth and 14 percent at the 0.5- to 1-inch depth.

Droplet Dynamics

In another project, Lehrsch found further evidence that irrigation comes with costs as well as benefits. "I studied how the kinetic energy in water droplets affects the infiltration of recently tilled soil," he says. "This is a key aspect of irrigation management, because when water can't infiltrate into the soil, it can't enter the crop's root zone where it's needed. Instead, it's lost through runoff." Just as important, the runoff increases erosion from the soil surface, which adds to sediment loads—and agricultural chemicals—in nearby waterways. It also exposes subsurface soil layers that are often less productive because they are less fertile and have poorer structure.

After just one irrigation, Lehrsch determined that the impact from water droplets delivered by certain center-pivot sprinklers increased the density of a freshly tilled silt loam by 18 percent and increased the soil's water-filled pore space by 35 percent. In addition, infiltration through certain small pores was reduced by almost 500 percent—a striking decrease.

Moreover, the single irrigation decreased hydraulic conductivity—the rate at which water moves through soil—by an average of 48 percent in the pores in the study. This decrease could cause soils to become saturated more quickly, which in turn would hasten runoff and decrease irrigation efficiency.

"Now that we know the impact water droplet energy can have on some soils, engineers can design better irrigation systems to minimize the negative effects irrigation can have on infiltration, soil structure, and crop emergence," Lehrsch says. "With this new information, farmers can better manage their center-pivot irrigation systems to maximize infiltration and reduce runoff and irrigation-induced erosion."—By **Ann Perry,** ARS.

This research is part of Water Availability and Watershed Management (#211), Climate Change, Soils, and Emissions (#212), and Agricultural and Industrial Byproducts (#214), three ARS national programs described at www.nps.ars.usda.gov.

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JAMES FOERSTER (D2498-2)

A sprinkler head is easily modified. The body (solid black) can house a single spray plate (orange, green, brown, or red) that alters droplet size and wetted diameter. The body attaches to either side of the dual-nozzle unit (far left): One side applies less water, usually early in the growing season; the other, more water, usually later in the growing season.

Flow Rate, and More

At the Agricultural Research Service's Northwest Irrigation and Soils Research Laboratory in Kimberly, Idaho, agricultural engineer Brad King and research leader Dave Bjorneberg compared how irrigation from four commercial center-pivot sprinklers affected potential runoff and erosion on four south-central Idaho soils.

Though their results were inconsistent, they did observe that at the end of six irrigations, a 50-percent reduction in sprinkler flow rate reduced runoff and soil erosion 60-80 percent. They concluded that reducing sprinkler flow rate early in the growing season—before the development of a crop canopy—could help reduce irrigation runoff and soil erosion linked to center-pivot sprinkler irrigation. In addition, the scientists observed that sprinklers distributing water drops more evenly over the wetted area had the highest runoff and sediment yield. Conversely, the lowest runoff and sediment yields were associated with sprinklers that distributed well-defined rotating streams of water drops, regardless of how much kinetic energy was transferred to the soil by the droplets.

The researchers followed up on this study with a laboratory investigation where they used a laser instrument to measure the size and velocity of individual water droplets distributed by five common center-pivot sprinklers. They found sprinklers distributing larger droplets did not always transfer more kinetic energy to the soil than sprinklers distributing smaller water droplets.

Given the somewhat contradictory findings, King and Bjorneberg concluded that much more remains to be learned about how different irrigation sprinklers affect runoff and erosion.—By **Ann Perry,** ARS.

150 Years of Making History

USDA's 150th Anniversary

May 15, 2012

The only thing that stands between the United States and an invasion of cattle-killing screwworms is a daily flight of airplanes flooding a 100-mile-wide section of the Isthmus of Panama with male screwworm flies raised in a laboratory and sterilized with radiation in Panama. The screwworm infestations of the past would probably come back if the releases stopped for a couple of months or so, says Dan Strickman, Agricultural Research Service national program leader for veterinary and medical entomology.

"This is a great example of agricultural research changing the history of this country, and it's a cutting-edge example of integrated pest management," Strickman adds.

This year marks the U.S. Department of Agriculture's 150th anniversary, making it a particularly appropriate time to look at this and other examples of history in the making.

The screwworm was wiped out of the United States by 1966 and Mexico by 1991. The purging continued south to include Central America until the "barrier" reached across the entire narrow Isthmus of Panama, and the screwworm was declared eradicated from Central and North America.

Before USDA eradicated the species from the United States, the screwworm—larvae of which eat living tissue of people and other animals—had plagued the Southwest, all of Florida, and parts of Georgia.

In 1937, the late Edward F. Knipling, then at a USDA laboratory in Menard, Texas, got the idea of flooding areas with sexually sterilized male screwworm flies. He believed that by releasing large numbers of sterile male flies, they would mate with nonsterile female screwworm flies and that the resulting "unsuccessful" mating would decrease the population over time, driving the flies to extinction.

When Knipling came up with the idea, there was no known way of sterilizing the male flies. Then one day he read an article by the Nobel Prize-winning geneticist Hermann Joseph Muller in *Scientific American* showing that x-rays sterilized male fruit flies without interfering with their normal functions.

Knipling wrote to Muller to see whether x-rays could be used to sterilize screwworm flies. Muller wrote back immediately, indicating his interest in the idea.

That exchange—and subsequent experiments demonstrating that the idea worked, including research by colleague Raymond Bushland showing that sterile male screwworms could be raised in a laboratory and function normally after release, including mating with nonsterile females—led to the historic screwworm eradication program.

The sterile insect technique has been used to eradicate screwworms elsewhere, including north Africa—where they were accidentally introduced—in the 1990s and most recently from Aruba. The technique has proved useful in controlling other pests as well, such as the Mediterranean fruit fly and the tsetse fly.

USDA screwworm research began under the auspices of the department's Bureau of Entomology and Plant Quarantine, which was transferred to the Agricultural Research Administration (which became the Agricultural Research Service by the end of 1953). The laboratory at Menard

Flesh-eating screwworms once plagued some southern U.S. states but have been eliminated from and kept out of the country because of continuing efforts of USDA scientists.

APHIS (D1742-1)

SCOTT BAUER (K7023-6)

Mediterranean fruit fly, a worldwide agricultural pest, is controlled by the same techniques used to eliminate screwworms.

was incorporated into the U.S. Livestock Insect Laboratory in 1946, which, in 1988, was renamed the Knipling-Bushland U.S. Livestock Insects Research Laboratory in honor of the two pioneering scientists. The facility, located in Kerrville, Texas, works on cattle fever ticks, horn flies, stable flies, and other livestock pests. Live screwworms are not allowed in the United States, however, so the lab can only work with DNA from the screwworm. The live-screwworm work is performed at the Screwworm Research Unit in Pacora, Panama, the site of a huge factory that produces sterile males for release. The Kerrville lab continues to research effective, less expensive methods to control insect pests of livestock.

Keeping Soil Where It Belongs

Another example of USDA research changing history occurred in 1938, when the USDA Soil Conservation Service [now the Natural Resources Conservation Service (NRCS)] and the Texas Agricultural Experiment Station created a laboratory in Bushland, Texas, in the wake of a dramatic wind erosion event. Poor agricultural practices for years, coupled with severe drought, left the soil of extensive U.S. farmland exposed. The result was a multiyear period of severe dust storms in the 1930s. Known as the "Dust Bowl," it was characterized by thick, black clouds of dirt and dust stretching across several states and millions of acres.

The Bushland lab's charge was to prevent the intolerable conditions of another potential Dust Bowl and to minimize wind erosion, working with other state experiment stations—such as those in Kansas and Ohio—and other USDA labs.

They developed stubble mulch tillage, leaving the residue of harvested crops on the land over winter to keep soil from blowing away and to save precious soil moisture. This was the forerunner of the highly successful practice of no-till and other forms of conservation tillage that drastically reduced erosion, whether by wind, rain, or snowmelt. ARS research was spurred further by the drought of the 1950s. At the time, there were limitations to stubble mulch, mainly lower yields, so ARS set out to overcome those limitations and, in time, succeeded in making conservation tillage an NRCS-recommended "best practice."

ARS Bushland scientists continue conservation tillage research to this day, improving techniques and adjusting to modern challenges. They have learned to harness wind energy to produce electricity for use in homes and on farms. They continue research on water conservation, taking advantage of the latest technology. Today, that means getting information on soil moisture from satellites.

Conservation tillage practices were developed by USDA scientists to keep soil in its place. The abundant residue on the soil of this no-till cotton crop planted into an unplowed cornfield will help prevent erosion from wind and rain.

DAVID NANCE (K7520-9)

GEORGE E. MARSH, NOAA, DEPT. OF COMMERCE (D2520-1)

NOAA, DEPT. OF COMMERCE (D2519-1)

Top: A dust storm approaching Stratford, Texas, in 1935. Above: Wind erosion in the Dust Bowl lasted for years in the 1930s, moving dramatic amounts of valuable soil—enough to practically bury this farm machine.

It is unlikely that the Great Plains will suffer another Dust Bowl as severe as the one in the 1930s. Isolated yet significant storms are inevitable, but the conservation tillage and crop residue management techniques developed from ARS research will certainly reduce the severity of dust storms in agricultural regions.

Six Nutrition Research Centers and Four Regional Research Centers

USDA-ARS human nutrition research also changed the history of the nation and continues to do so. This research has long affected the daily lives of Americans, although the average person may not realize it. Let's start with breakfast: The calorie content, fat percentage, and nutrient content on the label of the cereal box are required by the U.S. Food and Drug Administration (FDA), using ARS data that traces back to the work of Wilbur Olin Atwater, the father of American nutrition, in 1894. He began the food analysis that today is listed on food containers. He also pioneered the surveys of people's eating habits that continue to the present. Today, nutrition research is carried out by six ARS human nutrition centers in Arkansas, California, Maryland, Massachusetts, North Dakota, and Texas. For example,

SCOTT BAUER (K7242-20)

Dozens of improved products and new varieties of fruits, nuts, and vegetables emerge from the laboratories and greenhouses of the Agricultural Research Service.

definitive human feeding studies at the Beltsville, Maryland, center showed the health benefits of limiting trans fat consumption. This led to FDA requiring food labels to include trans fat content and to food companies reformulating products to lower their trans fat content.

Ironically, nutrition research in the early days was directed at making sure Americans got enough to eat; today, research has to deal with obesity problems as well.

Many new products in the home—both food and nonfood—were a result of USDA-ARS research beyond the human nutrition labs. Many of these were from research efforts at four regional research centers established in 1938 to find new uses for agricultural commodities. Today, all four of these centers are designated American Chemical Society historical landmarks for specific scientific achievements. Those centers, strategically located across the country—in California, Illinois, Louisiana, and Pennsylvania—were created to help end chronic farm depression by finding new, value-added uses for surplus crops. By the end of 1940 and early 1941, research began at the centers, and many new value-added products—still in use today—were created as a result.

Adding lactose-free milk to cereal? ARS technology is used to make that milk. That glass of orange juice made from frozen concentrate tracks to ARS's development in the 1950s of a way to freeze the concentrate. Popping a frozen waffle in the toaster? ARS developed techniques for freezing that waffle and other foods. ARS scientists began a project in 1948 that eventually led to nine principles for freezing vegetables that remain the industry standard. Jelly on toast? ARS had a hand in developing jelly from fruits.

More recently, ARS worked with industry partners to develop a process for making sunflower seed butter as an alternative to peanut butter for children allergic to peanuts. "Frozen orange juice, sunflower seed butter, and lactose-free milk are probably among the top food and drink products developed with ARS technology in terms of dollar value in sales," says David Klurfeld, ARS national program leader for human nutrition.

USDA-ARS successes from research conducted at the centers also include instant mashed potatoes, explosion-puffed dehydration technology used to dry foods, and the SuperSlurper starch-based product used in making super-absorbent diapers, baby powder, wound dressings, automotive products, and agricultural and horticultural products, to name a few. The list goes on:

a coating to keep fresh-cut fruit, like apple slices, from browning, now available at fast-food restaurants and grocery stores; Oatrim fat substitute made from oat bran, used in ice cream and other foods to lower fat and calorie content; Sucromalt low-glycemic sweetener used in some food products to help consumers stabilize and lower blood sugar levels; soy-based fuels, inks, and hydraulic fluids; and compostable bowls, cups, plates, and trays.

People who wake up between cotton sheets and put on cotton clothing—whether permanent press, wash-and-wear, or flame-retardant—may not realize that they are benefiting from ARS research on improving cotton quality, processing, and use.

The invention of durable press helped the cotton fabric industry reinvent itself after World War II. Since then, USDA-ARS research has also led to wash-and-wear and flame-retardant cotton fabrics.

SCOTT BAUER (K4549-1)

The War Effort and Beyond

ARS researchers started shaping history immediately, and their efforts supported the United States and allies in World War II. In 1940, ARS chemists in Peoria, Illinois—at the request of Great Britain—found a way to produce penicillin, discovered in 1928, as a powder suitable for medicine. Then they found a way to produce the drug in quantity, using their expertise in growing molds in large fermentation vats. By the end of 1942, 17 U.S. firms were making penicillin pills.

Sunflower seed butter is one of many products developed as a result of ARS research. It offers children allergic to peanuts another alternative.

PEGGY GREB (D2515-1)

Peoria researchers found a superior, more productive *Penicillium* strain on a moldy cantaloupe from a local market. They gave that mold to the drug companies, and the companies produced enough penicillin to treat allied soldiers wounded on D-Day.

The Peoria lab's expertise and techniques have been used in developing many other products—including the food thickener xanthan gum, biobased fuels, and other biobased products—and in modern genetic research.

As part of the U.S. Emergency Rubber Project during World War II—aimed at finding domestic rubber sources—research at Wyndmoor, Pennsylvania, and other USDA labs helped improve the production of synthetic rubber. Their research was essential to the Allied victory, and remains useful to this day for producing domestic rubber.

(K9422-1)

In his Peoria laboratory, USDA scientist Andrew Moyer discovered the process for mass producing penicillin.

ARS researchers developed DEET to repel mosquitoes and other pests during wartime while looking for alternatives to citronella—which was in short supply at the time. ARS also came up with techniques for making military clothing resistant to biting insects, mildew, rot, and oil-based liquid chemical weapons. Other wartime discoveries included better bandages, dextran (a blood plasma substitute made from sugar beet pulp and sugarcane), and MRE (Meals Ready to Eat) food items for the military.

Many of ARS's discoveries and techniques developed during wartime have led to peacetime uses that have extended to today.

In 1984, ARS technicians Kenneth Posey (left) and Dick Godwin conduct a Florida field test of mosquito repellents on skin and in military uniforms.

(K1654-18)

Abundant, Safe Food

ARS research has always had an international aspect. Perhaps the best example is the work leading up to the Green Revolution—a period of increased worldwide agricultural production. In 1946, an ARS agronomist collected seeds of short-statured wheats in Japan. These seeds were later distributed to various U.S. wheat breeders, including a team led by ARS breeder Orville Vogel, in Pullman, Washington. The group developed high-yielding, semi-dwarf wheat varieties that were further improved by the late Norman Borlaug, of the International Maize and Wheat Improvement Center, to avert famines worldwide.

Upton Sinclair's *The Jungle,* an exposé of meat-processing practices of the past, resulted in the Meat Inspection Act of 1906 and the beginnings of a formal food safety agency at USDA. Although USDA-ARS research has always had a food safety aspect, a formal national research program was created in 1997 with the Food Safety Initiative under President Bill Clinton.

Today, ARS's food safety research includes robotic inspections of poultry and goes beyond meat to include all foods. A good example is an effort over the past decade by ARS researchers at Clay Center, Nebraska, and their colleagues. These scientists have been sequencing genes to find those that can be used as markers for serotypes of *Escherichia coli* that produce Shiga toxin. Through this work, they have worked with industry partners to develop assays for Shiga toxin-producing *E. coli,* including *E. coli* O157:H7, which causes foodborne illness.

This food safety program traces back to earlier research: A USDA chemist in 1882 was one of the first to analyze the bacterium that causes tuberculosis. USDA scientists over the years also showed the value of pasteurizing milk and determined the cooking temperature needed to kill the pathogen that causes trichinosis.

The Objectives of USDA's First Leader

By signing a bill on May 15, 1862, President Abraham Lincoln established USDA. From there, history moved swiftly as the Morrill Land Grant College Act (July 2, 1862) was signed, authorizing public land grants for colleges to teach agriculture and mechanic arts and leading to the establishment of major state-operated agricultural research centers.

On July 1 of the same year, Isaac Newton was appointed the first commissioner of agriculture. The new commissioner listed seven original objectives in his first report as head of the new department. In 1889, USDA achieved cabinet status, and these seven objectives have continued to be pursued by the department's agencies to the present day.

(D2521-1)

A researcher examines strawberry cultures in a growth chamber in the 1980s.

KEITH WELLER (K7898-3)

Developed by ARS agricultural engineer Yud-Ren Chen, this automated system could help speed inspection of the billions of U.S. chickens processed annually.

7 Objectives of Isaac Newton, USDA's First Commissioner of Agriculture

1. Collecting, arranging, and publishing statistical and other useful agricultural information.
2. Introducing valuable plants and animals.
3. Answering inquiries of farmers regarding agriculture.
4. Testing agricultural implements.
5. Conducting chemical analyses of soils, grains, fruits, plants, vegetables, and manures.
6. Establishing a professorship of botany and entomology.
7. Establishing an agricultural library and museum.

Today, USDA continues to fulfill these objectives, and many more. ARS is particularly involved in objectives 2, 4, 5, and 7. Other USDA agencies are more involved with objectives 1, 3, and 6.

"Testing Agricultural Implements"

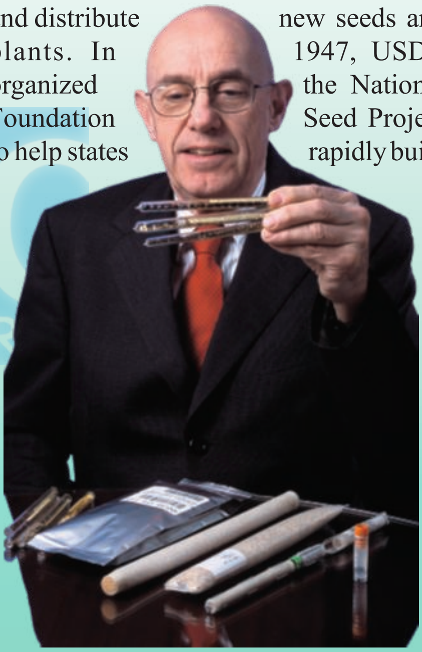
"Testing agricultural implements" was one of Newton's seven original objectives.

The National Soil Dynamics Laboratory, originally founded as the Farm Tillage Machinery Laboratory in 1933, is located on the campus of Auburn University in Auburn, Alabama. The lab was initially charged with researching tillage, associated traction practices, and machines used in cotton production, but its scope was soon extended to include all types of tillage, traction machinery, and practices. In 1957, the laboratory became the National Tillage Machinery Laboratory.

In its first 50 years, the laboratory contributed to the understanding of soil compaction and its management. In 1990, the American Society of Mechanical Engineers and the American Society of Agricultural Engineers designated the laboratory as a historic landmark.

Collect, Test, and Distribute New Seeds and Plants

The law that President Lincoln signed to create USDA authorized Newton and future department leaders to collect, test, and distribute new seeds and plants. In 1947, USDA organized the National Foundation Seed Project to help states rapidly build



STEPHEN AUSMUS (K10189-1)

At ARS's National Center for Genetic Resources Preservation in Fort Collins, Colorado, Henry Shands holds tubes from a long-term experiment designed to test the effects of storage receptacles and temperature on seed longevity.

KEITH WELLER (K7406-3)

ARS's germplasm collections preserve more than just plants and animals for future generations. Here, microbiologist Cletus Kurtzman retrieves yeasts stored at an extremely cold temperature (in liquid nitrogen) in the ARS Culture Collection.

up seed supplies. Today, ARS maintains a national system of seed storage banks, the National Plant Germplasm System. The system's 20 genebanks and support units hold germplasm for scientists, breeders, farmers, and others to use. "Germplasm" refers to the parts of plants and animals that are needed for reproduction, like seeds or semen.

More than half a million germplasm samples from around the world are stored in containers housed in secure vaults at the National Center for Genetic Resources Preservation (NCGRP), formerly known as the National Seed Storage Laboratory—the central bank of the system.The seeds are stored at low temperatures—either 0˚F or over liquid nitrogen at –292˚F. Each of the 19 other genebanks contains certain species of plants, whereas NCGRP contains backup versions of them all and is the only one that also stores animal germplasm.

"Introducing Valuable Plants and Animals"

Another of Newton's seven goals was "Introducing valuable plants and animals."

Over the last 150 years, numerous scientific discoveries and research milestones have contributed to U.S. animal and plant production, ensuring that our foods are abundant, safe, and sustainable. In that tradition, ARS's ability to respond to our nation's needs—either in adapting to food security threats or in offering solutions to consumer needs—is also evident in groundbreaking research that saved and helped revolutionize several industries.

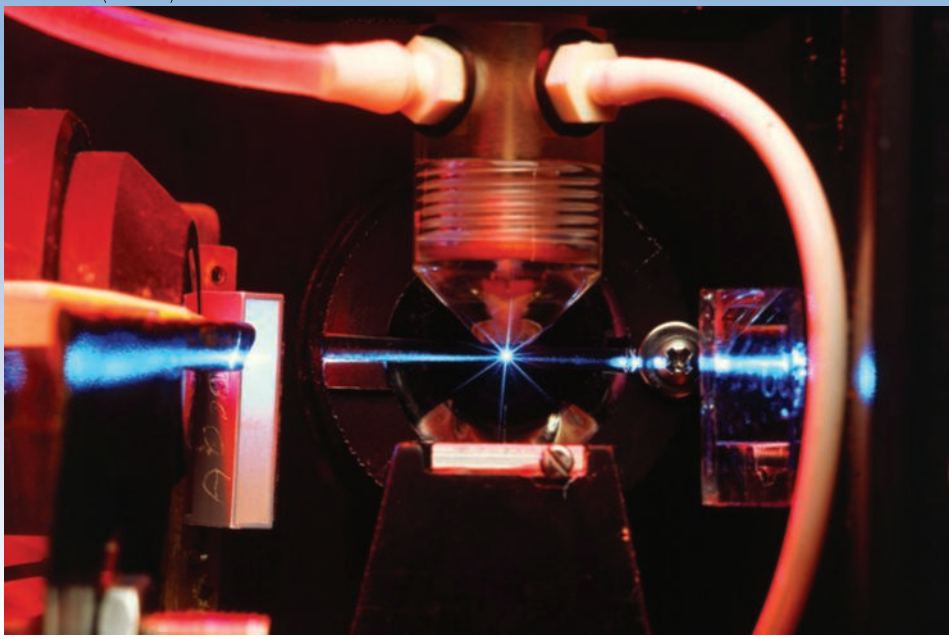
In 1833, hog cholera (also known as "classical swine fever") was first reported in the United States. Highly contagious to pigs and wild boar, the disease continued to spread, devastating the swine industry and ultimately jeopardizing pork production. Demonstrating its ability to respond in a crisis, ARS established the Hog Cholera Research Station in Ames, Iowa. The Ames station conducted research and diagnostic services on hog cholera until the National Animal Disease Laboratory opened in 1961 and later became the flagship for USDA's animal disease work. This lab continues to study major poultry and livestock diseases to help protect our nation's meat and poultry supply.

Germplasm collections preserve valuable genetic material for future generations. One of the many benefits of saving precious germplasm is protection against devastating diseases and pests and identification of important traits. The National Animal Germplasm Program houses animal germplasm from animals past and present. The collection contains semen from Hereford and Holstein bulls

SCOTT BAUER (K9441-1)

The National Animal Germplasm Program houses genetic material for swine and many other animals as an "insurance policy" against devastating diseases and other problems that might arise.

SCOTT BAUER (K4288-12)



The ARS-developed Beltsville Sperm Sexing Technology uses a fluorescent dye and a laser to identify and sort livestock sperm that will produce female progeny from those that will produce males.

from the 1950s to today. In addition, the repository has acquired semen samples from Limousin, Simmental, and Salers bulls that were originally imported from Europe in the late 1960s. Most recently, the repository has acquired a broad array of genetically diverse samples of Jersey cattle from Jersey Island, where the breed originated and from where it was first imported into the United States in the 1800s. The repository also houses germplasm from numerous sheep and swine breeds, including some from as far back as 1965. These collections serve as germplasm "insurance policies" for the animal production industries, protecting against loss of valuable germplasm diversity.

In 1935, USDA initiated its National Poultry Improvement Plan to improve production and marketing qualities of chickens and turkeys through performance testing. Years later, a major milestone was reached, changing the meat quality of turkey: ARS released the Beltsville Small White, a small, meaty, full-breasted turkey, in 1941. This bird met consumer needs and demands for a smaller turkey. Before the Beltsville Small White, the average weight of an adult tom turkey was a whopping 33 pounds. Some breeds were too big to fit in apartment-sized ovens and refrigerators. Thanks to USDA, today's turkeys and chickens—enjoyed year round—are extremely efficient and yield an abundance of lean meat.

In 1917, USDA started a long-term dairy herd improvement program that has led to a tremendous increase in milk production. The program continues to this day under ARS and is setting the standard domestically and internationally for genetic and genomic technology development and implementation.

The ARS Hereford cattle improvement breeding program began in 1934 in Miles City, Montana. Today the average Hereford contains more than 40 percent genetic material from the ARS Line 1 Hereford cattle. Research in beef cattle genetics at the U.S. Meat Animal Research Center quantified the value of numerous breeds and crosses for the beef industry. This research was extremely valuable and was used to develop most industry crossbreeding programs. Beef industry research in efficiency, reproduction, meat quality, and genetics is ongoing at ARS.

USDA scientists have changed the food industry—developing vaccines, processes, and technologies to protect our food, from the farm to our tables. When Marek's disease posed a threat to the poultry industry, ARS poultry scientists in East Lansing, Michigan, were first to develop a way to vaccinate chicken embryos against the disease. This disease attacks birds' nervous systems and kills more birds than any other disease. In 1987, ARS entered into its very first cooperative research and development agreement (CRADA) with Embrex Inc., of Research Triangle Park, North Carolina. This was the first

Beltsville Small White turkey. Released in 1941 by USDA, this turkey met consumer needs for a smaller bird with more breast meat.

(K9639-1)

CRADA between any private company and government lab under the Federal Technology Transfer Act of 1986. The act allowed more flexibility in federal-industry research and development. ARS licensed its egg-infection technology to Embrex, which enabled the company to innoculate 20,000 to 50,000 eggs per hour.

Other research has led to vaccines for H1N1 influenza virus, foot and mouth disease, mastitis, porcine reproductive and respiratory syndrome, avian leukosis virus, and brucellosis.

Aquaculture is an industry that provides half of the world's seafood. ARS's aquaculture program has proven invaluable to U.S. fish farmers, from improving production practices to breeding and improving fish varieties, like catfish, salmon, trout, and tilapia, to developing new vaccines to ensure healthy fish. Notably, ARS scientists in Auburn developed several vaccines that protect fish against major diseases, like those caused by *Streptococcus iniae* and *Flavobacter columnaris,* emerging bacterial pathogens in cultivated catfish, tilapia, hybrid striped bass, rainbow trout, and others. These vaccines offer alternatives to antibiotics or chemical treatments.

PEGGY GREB (K9216-9)

Market-size catfish ready for harvest. ARS scientists have developed vaccines that protect catfish, tilapia, hybrid striped bass, rainbow trout, and other fish from major diseases. The vaccines offer alternatives to antibiotics or chemical treatments.

Groundbreaking animal research includes inventing highly sophisticated breeding techniques and tools. ARS researchers developed, patented, and licensed the Beltsville Sperm Sexing Technology—a method that separates female-producing sperm from male-producing sperm based on DNA content. The technique helps speed the rate at which farmers can achieve genetic improvement while reducing production costs. More recent achievements include working with industry and university partners to develop a BeadChip, a genomic method used to analyze cattle DNA—and now sheep, pig, and plant DNA—to identify bulls that produce offspring with optimum milk production and other traits.

USDA scientists have conducted decades of crop production research to ensure a sustainable bounty of fresh fruits, vegetables, and other staples, like peanuts, wheat, rice, and soybeans—all while protecting our environment. Many new varieties of fruits and vegetables—including grapes, oranges, blueberries, cranberries, peaches, apricots, tomatoes, watermelon, potatoes, carrots, lettuce, cucumbers, peppers, apples, and more—were developed at USDA-ARS labs.

Red seedless table grapes were all but unknown to the U.S. consumer before USDA-ARS released the seedless grape Flame in 1973. In 1989, ARS released Crimson, which further increased table grape popularity. These two varieties alone, grown extensively by both domestic and foreign producers, make up a majority of today's consumer market, although several

USDA scientists have conducted decades of crop production research to ensure a sustainable bounty of fresh fruits, vegetables, and other staples, like peanuts, wheat, rice, and soybeans—all while protecting our environment.

PEGGY GREB (K8666-1)

(D2522-1)

KEITH WELLER (K4616-1)

ARS is always working to improve the foods you consume. Left: Researchers in the 1980s examine protein profiles of soybean cultivars.

Center: Most of the U.S. citrus grown today was developed from ARS varieties or rootstock and is high yielding and disease resistant.

Right: Today's carrots, onions, garlic, and cucumbers—thanks to ARS research—taste better and have more nutrients.

SCOTT BAUER (K7246-1)

newer USDA-ARS varieties have also taken hold of the U.S. table grape industry: Autumn Seedless, Thompson, Sweet Scarlet, Scarlet Royal, and Autumn King.

More than 70 percent of the citrus grown in the United States is from ARS-developed varieties or rootstock. ARS researchers in Florida have developed citrus that is high yielding, disease resistant, more colorful, and has a longer shelf life. Current research efforts are focused on protecting the U.S. citrus crop from citrus greening disease, one of the most severe citrus diseases.

Alone or with other partners, ARS conducts important environmental studies across the United States. A University of Maryland PhD student collects water samples from the Choptank River Watershed.

PEGGY GREB (D1878-1)

Nearly every head of iceberg lettuce you'll find in a supermarket owes its parentage to the work of ARS plant breeders. The ARS gene bank contains more than 2,000 types of lettuce. Researchers in California recently released three new leaf lettuce breeding lines with resistance to corky root, a serious disease of lettuce.

Blueberries, a nutritional power fruit, were not always the stars they are today. In the Gulf Coast region, growing blueberry crops is possible, thanks to ARS early-ripening varieties. Today, more than 10,000 acres are planted to Dixie—an ARS-developed variety—with more than 4,000 acres thriving in Texas, Louisiana, and Alabama. ARS researchers are now studying the compounds in blueberries and other berries and the effects of those compounds on nutrition and health.

Potatoes are popular whole, sliced, diced, mashed, or chipped. ARS's potato breeding program continues to deliver new varieties that are resistant to various diseases and pests and are high in nutrition. Recent research also targets zebra chip disease, a problem for potato growers since it was detected in 2000. Since then, it has caused millions of dollars in production and processing losses.

These are but a few of many examples of the successful fruit and vegetable research at USDA-ARS. One cannot visit a supermarket or farmers market without encountering a fruit or vegetable that got its start at ARS.

"Establishing an Agricultural Library"

Newton's original goals also included "establishing an agricultural library." This goal was an outgrowth of the 1862 act that established USDA and ordered the commissioner "to acquire and preserve . . . all information concerning agriculture." Newton wasted no time. By 1863, around 1,000 volumes from the Agricultural Division of the Patent Office were moved to USDA to form the nucleus of this new library. After 100 years of service, it was designated the "National Agricultural Library" (NAL) and moved to Beltsville, Maryland.

Today, while that building still houses seemingly endless stacks of papers, books, and other items, the library's real growth comes digitally, with new, often specialized content finding its way to the Web for NAL's global customers. The NAL Digital Collections currently delivers nearly 25,000 USDA full-text publications, 45,000 scholarly articles, and the 7,584 technically accurate watercolor paintings, prints, and drawings of fruits and nuts that comprise the USDA Pomological Watercolor Collection. This ever-growing collection knocks down the barriers to finding government-produced agricultural research and informative historical works.

Under development is NAL's Life Cycle Assessment Digital Commons. It collects data that reflects how products derived from agriculture are grown, made, and used. Currently, such life cycle data is dispersed and often difficult to find, but the Digital Commons will bring that data from across the agricultural sector into one easy-to-use location.

Watercolor in the Rare and Special Collections of the National Agricultural Library.

(K9982-11)

"Conducting Chemical Analyses of Soils, Grains, Fruits, Plants, Vegetables, and Manures"

Newton's goal of "Conducting chemical analyses of soils, grains, fruits, plants, vegetables, and manures" is now done with technology beyond Newton's imagination. ARS scientists at Beltsville developed the Beltsville Universal Computerized Spectrophotometer, which led to near-infrared instruments to analyze and grade bulk grains like wheat and corn—as well as perform forage quality tests, manure analysis, and switchgrass grading for ethanol potential. Researchers continue to expand these techniques to develop cost-effective ways to rapidly improve bioenergy crops.

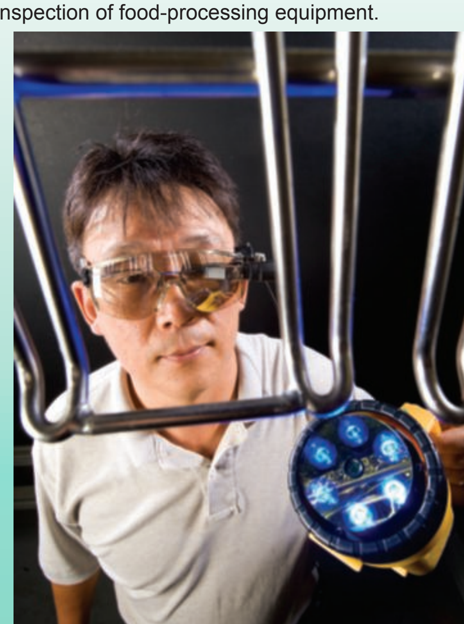
ARS researchers are also using innovative remote sensing techniques to develop close-up, hands-off inspection of meat and poultry, fruits, vegetables, and whole-kernel grains. Recent developments include an automated hyperspectral image analysis system—which uses digital imaging and visible/near-infrared spectroscopy—that can scan 140 poultry carcasses per minute during food safety inspection. Similar systems are used for quality inspection and detecting contaminants in fruits, vegetables, and grain to reduce their potential for causing foodborne illnesses.

ARS continues its research in these and other areas with an emphasis on lessening our global footprint. USDA researchers are learning more about how weather, climate, and water resources affect agricultural production and the environment. Today, USDA researchers and industry and university partners work collaboratively to explore environmental practices that will benefit farmers, consumers, and the world.

At USDA's sesquicentennial, ARS and all the other agencies that make up the department today are continuing to follow Newton's "Seven Commandments"—but with ever-changing technologies and challenges, most of them unimagined in 1862.—By **Don Comis,** formerly with ARS, **Tara Weaver-Missick,** ARS, and **Robert Sowers,** ARS.✻

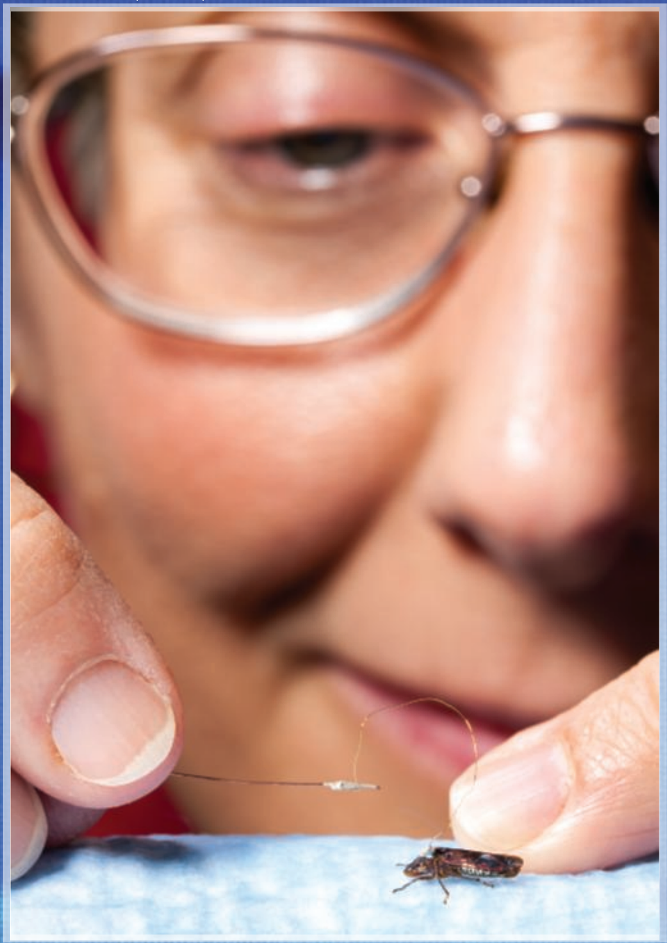
Below: Outdoors and indoors, ARS scientists tackle a variety of problems. Left: Agronomist Edgar E. Hartwig devoted half a century to soybean research, developing productive plants with resistance to insects, nematodes, and diseases. Right: Biophysicist Moon Kim tests a portable imaging device equipped with a head-mount display for sanitation inspection of food-processing equipment.

KEITH WELLER (K5272-2)



STEPHEN AUSMUS (D611-1)

STEPHEN AUSMUS (D2480-11)



Entomologist Elaine Backus demonstrates how she uses silver print paint to attach a pure gold wire—half the thickness of a human hair—to a glassy-winged sharpshooter, *Homalodisca vitripennis*.

STEPHEN AUSMUS (D2481-1)

New Tool Opens a Bigger Window to Insect-Plant Warfare

A young adult glassy-winged sharpshooter wired up while it's feeding on a plant is being recorded by an AC-DC EPG.

When an aphid, leafhopper, or psyllid lands on a plant to feed, it begins a process of chemical warfare. As piercing-sucking insects, they use needle-like stylets to insert saliva into plant tissues and open a pathway to ingest fluids critical to the plant's survival. When punctured, the plant senses the attack and secretes proteins and other chemical defenses to prevent fluids from being pulled out, thus creating a stress on the plant. This warfare costs growers billions of dollars each year in lost ornamentals, vegetables, citrus, and other important agricultural crops.

Because much of the action takes place in the plant's interior, a scientific tool called an "electrical penetration graph" (EPG) is critical for peering into the process. To use it, researchers connect the insect and plant to an electronic monitor that, like an electrocardiogram, reads electrical charges produced by tiny changes in voltage that occur as the insect feeds. A new type of EPG, developed by Elaine Backus, an ARS entomologist at the San Joaquin Valley Agricultural Sciences Center, in Parlier, California, and the late William Bennett, formerly from the University of Missouri, is giving scientists the clearest window yet into the wars waged between piercing-sucking insects and the plants they infest. Because these insects are often carriers of plant pathogens that are transmitted through feeding, EPG can also illuminate how pathogens are injected into the plant to start the infection process.

The new EPG—called the "AC-DC correlation monitor"—is much more versatile than any of its predecessors and is currently being used by researchers around the country in ways expected to broaden our understanding of how plant-feeding insects cause so much damage. "We've expanded the flexibility of the current technology so that we're now able to evaluate any insect that pierces or breaks the surface of a plant and study the feeding mechanisms and the pathogen-inoculation process in more detail," Backus says.

She and Bennett described their AC-DC monitor in a 2009 issue of the *Journal of Insect Physiology.* Backus also used it in a series of studies published in the *Annals of the Entomological Society of America.* These studies focused on the critical role that saliva plays when the glassy-winged sharpshooter injects the Pierce's disease bacterium, *Xylella fastidiosa,* into grapes. Backus believes that the saliva loosens bacteria living in the gut and stylets and carries them into the plant when the mixture is "spit up" during feeding. That inoculation process begins the spread of the disease throughout the plant. Backus could not have gained these insights without the AC-DC monitor.

Backus has promoted the monitor's versatility at scientific workshops and conferences. In recent years, Bennett built more than a dozen monitors worldwide for scientists who were willing to reimburse him for the costs. Among its fans are researchers at Oklahoma State University, who are using it to study how plant pathogens are injected into watermelons by squash bugs and into corn by corn leafhoppers.

"We've found that you can use it to gather all sorts of information," says Astri Wayadande, a vector entomologist at Oklahoma State University.

Having such technology should prove useful to entomologists and to plant breeders. A goal for breeders is to develop plants with genes that make them capable of resisting pathogens. To find those genes, it would help to learn more about the pathogen-inoculation process so that, ideally, you could identify steps in the process that can be partially or completely blocked, either by silencing or turning on the right genes.

A Scientific Workhorse

At least seven different EPG systems have been made by scientists around the world. Over the past 30 years, the monitors have earned a reputation as a workhorse among researchers who study aphids and a handful of other piercing-sucking insects. Scientists have reported on them in more than 400 peer-reviewed papers.

To use them, researchers glue one end of a gold wire to the insect's dorsal area (its back) and insert another wire into the moist soil around the plant. This establishes a continuous electrical circuit through the monitor that can detect even miniscule changes in voltage that occur when the insect pierces the plant, releases saliva, or draws juice (ingests) from the plant into its digestive system.

A blue-green sharpshooter, *Graphocephala atropunctata,* being monitored during feeding.

ELAINE BACKUS (D2503-1)

Fluids like saliva carry electrical charges, and the movement of saliva into the plant causes the levels of those charges to fluctuate. That in turn produces waveforms that scientists can read to decipher details about the feeding and pathogen-inoculation process.

Waveforms are also produced by fluid fluctuations caused by movements of the insect's internal valves and pumps as it feeds or by the breaking of plant cell membranes. When researchers study different species of insects, they correlate the waveforms produced by each species to different steps in the feeding process, such as the insertion of saliva, the initial tasting, and ingestion. For each insect, there are unique changes in waveforms from ingestion, salivation, and stylet movement. "It is a window into the internal mechanisms that the insect uses when it feeds and into the plant responses to the feeding," Backus says.

The New Monitor's Advantages

Traditionally, monitors have been designed to work with either AC or DC current. Because of the physics that govern electricity and the flow of electrical current, researchers have gotten the best results when using AC monitors to study larger insects and DC monitors to study smaller ones. Ideally, a monitor should be capable of studying a variety of insect sizes.

As the name implies, the AC-DC monitor incorporates features from both AC and DC monitors, making it more versatile. The user can adjust the settings to the size of the insect being studied. They can use it to study all kinds of insects—not just plant feeders—to see what happens when a tick, mite, mosquito, bed bug, deer fly, or any biting or chewing insect pierces the surface of a plant or animal when it feeds, Backus says.

Entomologists will be able to view the feeding process in detail for more insects than ever before and compare the feeding of pathogen-bearing insects with those that are pathogen-free. Many pathogens, both animal and plant, affect the insects that carry them as well as the plants or animals they infect.

Wayadande is using the monitor to study how squash bugs transmit *Serratia marcescens,* the bacterium that causes cucurbit yellow vine disease, to watermelon and other cucurbits. She hopes to find cultivars that breeders can use to develop commercial varieties that resist the pathogen. "We don't really understand how squash bugs feed, how they damage the plant, and how they inoculate it with plant pathogenic bacteria and cause disease. The monitor helps us study all of these things," she says.

Wayadande also used the monitor to study and publish research on how leafhoppers infect corn with corn stunt spiroplasma, a common corn pest. Squash bugs are much larger than leafhoppers, so before Backus and Bennett's monitor came along, Wayadande says she probably would have had to use two different monitors to effectively monitor the two insects. But with the AC-DC monitor, she collected quality data on both.

"It's a wonderfully versatile system," she says.—By **Dennis O'Brien,** ARS.

This research is part of Plant Diseases, an ARS national program (#303) described at www.nps.ars.usda.gov.

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Elaine Backus adjusts the position of a glassy-winged sharpshooter while its feeding is recorded by an AC-DC EPG monitor. Backus uses the technique to study how the insect transmits Pierce's disease bacteria into grape.

STEPHEN AUSMUS (D2479-11)

RICHARD EVANS (D2500-1)

Adult kudzu bug, *Megacopta cribraria.*

ARS Assists in Fight Against Kudzu Bug

Don't let its common name fool you: The kudzu bug is not your friend.

Sure, this distant relative of the brown marmorated stink bug will feed voraciously on the stems of kudzu, the "Vine That Ate the South." But *Megacopta cribraria* also has a taste for soybean and other legumes. In Georgia, where this native of Asia was first discovered in the United States in October 2009, there's worry that the pest will set its sights on peanut, endangering a $2 billion crop that supplies nearly 50 percent of America's peanuts (Georgia Peanut Commission, 2009).

Like the brown marmorated stink bug, *Megacopta*—also known as the "bean plataspid"—seeks shelter inside homes, buildings, and vehicles during the fall as temperatures cool. And when disturbed, it too emits a foul smell.

Researchers, however, haven't been idle. For example, at the Agricultural Research Service's Stoneville [Mississippi] Quarantine Research Facility, entomologist Walker Jones is evaluating a secret weapon in the form of *Paratelenomus saccharalis,* a tiny black wasp received, under permit, from Japan in 2011.

Though nonstinging and harmless to humans, pets, and other animals, *P. saccharalis* is a top natural enemy of *Megacopta* in Japan. More specifically, the wasp lays its eggs in the bug's eggs. Upon hatching, the wasp's maggotlike brood devour the bug's own developing embryos, reducing the size of the next generation.

In North America, there are no specific natural enemies to keep the pest's numbers in check—hence the interest in *P. saccharalis* for potential use in biocontrol programs. But first, the wasp must pass muster on a long list of requirements assuring its host specificity and environmental safety—starting with quarantine trials at Stoneville.

Megacopta belongs to an insect family that doesn't occur naturally anywhere in the Americas. Thus, importing its coevolved natural enemies isn't expected to endanger native U.S. bug species. If research bears this out, getting permission to release a promising host-specific natural enemy like *P. saccharalis* will be facilitated. Its successful establishment would not only reduce crop damage, but also curb the rate and intensity of *Megacopta's* spread.

"I am presently screening eggs of native species of related bugs to see if it will attack them, and so far, it doesn't look like it will," reports Jones, who leads ARS's Biological Control of Pests Research Unit in Stoneville. He's conducting the evaluations using a steady supply of bugs, representing 4 families and 15 species, sent by colleagues from ARS, private industry, and universities, including the University of Georgia and Clemson University.

Cooperators in Asia and at ARS's European Biological Control Laboratory in Montpellier, France, are also searching for natural enemies.

On a related front, Jones's lab has devised a procedure for freezing *Megacopta* eggs and thawing them as needed, which will help with timing the mass production and release of the wasps.

Besides the wasp evaluations, this effort includes tracking *Megacopta* (it has spread to Alabama, North Carolina, South Carolina, Tennessee, and Virginia) and genetic fingerprinting. Using this sophisticated procedure, U.S. scientists recently matched DNA from Georgia's *Megacopta* population to indigenous populations of the bug in Japan, a finding that should help them discover how the pest arrived in the United States.

Meanwhile, more is being learned about *Megacopta's* basic biology, host-crop range, economic impact, chemical control, and vulnerability to native predators, parasites, or pathogens. Researchers want to provide farmers with an arsenal of weaponry to choose from. It may be a few years before egg-parasitizing wasps are patrolling crop fields, but chances are the bug will still be around.—By **Jan Suszkiw,** ARS.

This research is part of Crop Protection and Quarantine, an ARS national program (#304) described at www.nps.ars.usda.gov.

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Genetics and Bermudagrass
It's Not Easy Being Uniformly Green

Golfers and golf course superintendents expect a lot from their putting greens. They want fine, lush, carpetlike surfaces that a ball will roll smoothly across. They also want a grass that tolerates frequent low mowing, has uniform color and texture, tolerates pests and cold temperatures, and offers a dense canopy that shades out weeds to minimize the need for herbicides.

Southern putting greens are made up of single cultivars of bermudagrass, but golf course superintendents have complained for years about the appearance of nonuniform plants, or "off-types," that can throw off the green's appearance and "playability." The bermudagrass cultivar Tifgreen, released in 1956, launched the era of high-quality, vegetatively propagated turfgrasses, but has also led to problems with the appearance of off-types on putting greens. Off-types can be caused by bermudagrass weeds or mutation of the cultivar. Mowing as well as birds and other natural phenomena increase the risk of weeds appearing on putting greens. Herbicides, ultraviolet light in sunlight, and errors during normal DNA replication can also induce mutations in the grass itself. The resulting inconsistencies have cost golf courses and sod farms millions of dollars over the years, forcing them to kill and reestablish entire greens.

Fortunately, help is available from experts like Karen Harris-Shultz, a geneticist in the Agricultural Research Service's Crop Genetics and Breeding Research Unit in Tifton, Georgia. Harris-Shultz uses the plant's DNA to tell one type of bermudagrass from another and identify unwanted types of grass. She has developed a new tool to help distinguish among the different cultivars and improve on those diagnoses.

Golf course superintendents and sod farm managers often send off-type samples to Harris-Shultz for analysis. They need to know the identity of off-type on their greens before deciding how to proceed. Sometimes, after killing off a putting green to renovate it, they fear that the old grass wasn't killed entirely before the new grass was planted. They often want to know whether their off-type patches are caused by a previously planted cultivar, a bermudagrass weed, or a mutation of their planted cultivar.

"Turfgrasses are a major business, and if you're selling turf or sod, you want it to be stable, not constantly mutating and changing," says Harris-Shultz.

But even with the best molecular tools, the grass varieties are so alike that it is sometimes hard to tell them apart. The lines used on putting greens throughout the southeastern United States are all offshoots of varieties developed more than 40 years ago by the late Glenn Burton, a former ARS grass breeder in Tifton. Many bermudagrass cultivars are vegetatively propagated monocultures, and the close genetic similarity within the Tifgreen family makes it hard to tell cultivars apart.

Harris-Shultz collected 15 Tifgreen-derived cultivars from golf courses and research partners, extracted DNA from them, and with the help of an existing DNA database, she developed a tool to help distinguish bermudagrass cultivars and identify contaminants. She used a library of expressed sequence tags, which are unique gene segments, for bermudagrasses and 23 previously discovered simple sequence repeat markers, which are short repeating segments of DNA. The results, published in the *Journal of the American Society of Horticultural Sciences,* identify "repeatable polymorphic fragments" of DNA that are unique for each cultivar and can be used not only to distinguish among the different grasses, but also to trace relationships between them.—By **Dennis O'Brien,** ARS.

This research is part of Pasture, Forage, and Rangeland Systems (#215), an ARS national program described at www.nps.ars.usda.gov.

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After establishment, a new putting green usually starts off having a uniform appearance if it's free of weeds. But mutations in a bermudagrass green, in time, can cause off-types of bermudagrass to appear. A new genetic tool developed by ARS geneticist Karen Harris-Shultz can now distinguish the mutants from the desired grass.

JACK DYKINGA (K7087-19)

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