Public Research and Technology Transfer in US Agriculture: The Role of USDA

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Abstract Agriculture has been of fundamental and growing importance from the earliest days of human society. Over millennia, farmers have domesticated and improved a wide array of crops and livestock and passed their knowledge and experience down over generations. As the challenge to feed an ever-growing world population has increased, however, so has the need for ever greater levels of production. The latest science and technological advances undergird the success of modern agriculture. Virtually every item in a typical meal is available, at least in part, because of scientific and technological advances that have led to increased production, protection from pests or disease, or enhancements to their nutritional value. This vast array of research activities can be clearly seen in the story behind the daily Western breakfast table.

When the United States was young, agriculture was the major part of its economy, engaging the vast majority of the nation's people. Crops were grown repeatedly on a plot of land until the soil was exhausted, making it essential to move west in search of new land. But as the Civil War closed in, it was President Abraham Lincoln, himself the son of a farmer, who sought to formalize the growth, development, and science of agriculture. The act of the 37th Congress signed into law by Lincoln on May 15, 1862, established agriculture as the purpose of a federal government department without Cabinet rank (Grover Cleveland raised it to the Cabinet in 1889). The act charged the Commissioner of Agriculture to:

> "…acquire and preserve in his Department all information concerning agriculture which he can obtain by means of books and correspondence, and by practical and scientific experiments *[emphasis added]*, (accurate records of which experiments shall be kept in his office,) by the collection of statistics, and by any other appropriate means within his power;…."

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Subsequently, the Morrill Acts (1862, 1890) created land-grant colleges (one of Lincoln's other priorities); the Hatch Act (1887) funded state agricultural experiment stations; and the Smith Lever Act (1914) funded each state's Cooperative Extension Service. Thus, Lincoln's vision grew and developed, and today, scientific innovation is integral to a vibrant and productive US agriculture.

USDA's modern research operations span multiple agencies and billions of dollars in congressional appropriations. But within all of USDA's congressionally authorized budget ($139.7 billion in Fiscal Year 2015), the largest investment in agricultural research occurs in the agencies that comprise the research, education, and economics mission area, including (in Fiscal Year 2015) the Agricultural Research Service (ARS) ($1.1 billion) and the Economic Research Service (ERS) ($0.1 billion), which are intramural agencies; the National Institute of Food and Agriculture (NIFA) ($1.5 billion), funding state programs and extramural programs (including competitive research); and the National Agricultural Statistics Service (NASS) ($0.2 billion), which conducts surveys and issues reports on agricultural production, economics, demographics, and the environment (e.g., the Census of Agriculture). Other USDA agencies, such as the US Forest Service (USFS) and the Animal and Plant Health Inspection Service (APHIS), conduct research in specific areas.

Today, research across these many agencies encompasses hundreds of locations and thousands of scientists and technicians. With today's scope, it is fortunate indeed that the modern Secretary of Agriculture no longer is held to the requirement of that first Commissioner of Agriculture (the interestingly named Isaac Newton; USDA 1969) that records of research "…be kept in his office…."

The combination of department-centered intramural research and largely university-centered extramurally funded research is a hallmark of publicly funded agricultural research in the United States. The highly complementary nature of the intramural and extramural programs promotes research within government (through intramural programs) and in academia and the private sector (through NIFA's extramural research support). The impact of over 150 years of these scientific investments is impossible to document in one place. Even a rudimentary, highly selective, simple listing of accomplishments is extraordinary in its length (http://www.ars.usda.gov/oc/timeline/comp/, accessed October 11, 2016). A visual impact of this sustained public investment in agricultural science can be seen in a walk down the aisles of any modern American supermarket.

But perhaps an even better way for an individual to realize the impact of USDA science is at the breakfast table. Most, if not all, food found there have been improved or protected in some way through the efforts of USDA and USDA-funded researchers.

Everyone eats breakfast of some sort, if not by time of day, or food type, then only by definition. Breakfast food items vary tremendously around the world, and there is great diversity in the quantities and varieties of foods on breakfast tables every morning across the United States as well. A big family breakfast, or a well-stocked breakfast buffet in a hotel, may offer dozens of fresh, processed, or cooked items. Few people would eat some of everything in such a setting (although therein lies the introduction to a potential discussion of the obesity epidemic in America and elsewhere). But considering even a handful of items that might be on a typical American breakfast table illustrates the breadth and impact of USDA's scientific endeavors.

For many of us, the day begins with a glass of orange juice. During World War II, USDA researchers, along with members of the Florida Citrus Commission, developed the processes that led to frozen concentrated orange juice (Liu et al 2012; Kelley 1993), helping establish key aspects of the modern orange juice industry and making it almost synonymous with breakfast. But today, orange juice production faces one of the most potentially disastrous threats it has ever encountered in a disease called citrus greening (technically, Huanglongbing or HLB), for which there is no cure. This disease has virtually eliminated commercial citrus production everywhere it has become established and is probably the most difficult plant disease to control in any modern crop (Gottwald 2010). There is no cure for HLB, and until recently, all commercial citrus varieties were susceptible to its devastating effects. Infected trees produce fruits that are green, misshapen, bitter, and unsuitable for juice. Most trees, if they do not die within a few years, must be destroyed to prevent further spread of the disease.

The annual economic loss to Florida from HLB has been estimated to be just over $1 billion (Farnsworth et al. 2014). It has reduced citrus production in Florida by over 70% since the disease was first recognized in 2005 (Bouffard 2016). However, USDA scientists and partners who are studying the presumed bacterial pathogen (*Candidatus Liberibacter asiaticus*; CLas) and the Asian citrus psyllid (*Diaphorina citri*) that transmits it from infected trees are pursuing multiple approaches. These include insecticides to control the psyllid; removal of infected trees; antimicrobials as therapy in an attempt to "cure" infected trees or reduce the symptoms that make them unproductive (Yang et al. 2016; Zhang et al. 2014); use of tolerant rootstocks and scion cultivars (sweet orange, mandarin, etc.) that are being developed by the USDA-ARS, the University of Florida, and the University of California (Bowman et al. 2016); thermotherapy (Doud et al. 2012); and a diverse set of early detection methods for the CLas itself or other signs of infection based on specific tree responses (Hartung and Levy 2006). Even dogs have been trained to detect non-symptomatic infected trees – under controlled conditions – with great accuracy (Berger 2014; Mittelman 2016), but they remain to be fully tested under field conditions where the infection status of trees is unknown. For the long term, USDA scientists are developing resistant varieties by conventional breeding (Bowman et al. 2016) and, for the future, are pursuing biotechnological solutions that might control the insect, block transmission, or introduce novel genes to combat the disease.

Aside from orange juice, fresh fruit is part of many breakfasts. However, breeding new varieties of fruits with better flavor, size, color, or disease resistance can be a lengthy process that takes many years. The plants must be grown from seed to maturity, often taking 3–10 years, then the most promising are selected and bred, and the offspring, in turn, are grown another 3–10 years to produce seed. The plants from this seed are bred to still others with needed traits, which are again selected and bred over yet another lengthy period. Only after several such multiyear cycles does a new and improved variety begin to emerge. Thus, a plant breeder may be able to produce only a handful of new varieties in his or her entire career.

A new technology called FasTrack, developed by ARS scientist for plums (a common fresh or dried fruit on the breakfast table), speeds all that up (Yao 2011). A gene originally found in poplar trees produces almost immediate and continuous flowering and fruit production in plums, thus eliminating the years of growth to maturity. As a result, the time between successive breeding events is greatly reduced, and the finished variety emerges much sooner. Once the desired variety is achieved, the poplar gene is eliminated through traditional breeding methods. The resulting new plum variety lacks that foreign gene, which was used only to speed up the breeding process, so regulatory or other issues related to release of genetically modified organisms are not a concern. Best of all, what was originally up to 10 years between each cross is reduced to just 1 year. Improved varieties can be developed five to six times (or more) faster than pre-FasTrack breeding methods (Scorza et al. 2012; Yao 2011; van Nocker and Gardiner 2014). Applications to species other than plum are being developed.

The FasTrack technology also illustrates how USDA research can have benefits and applications not imagined during the original project. The National Aeronautics and Space Administration (NASA) is cooperating with USDA to examine developing FasTrack applications for future interplanetary missions where having a plant that could rapidly produce nutritious fruit would be a major benefit to astronauts facing months or years away from Earth (Graham et al. 2015).

Newly emerging technologies, such as the gene-editing CRISPR/Cas methods, coupled with FasTrack, promise a further enhanced ability to create new varieties without the need for either foreign genes or lengthy breeding cycles (Xiong et al. 2015). So we can expect a variety of fresh fruit to remain an integral part of the breakfast table.

A breakfast omelet literally folds in several ingredients. It contains eggs, of course, and probably some cheese, maybe tomato or peppers, and perhaps some fresh vegetables such as broccoli. All have been improved in some way through USDA research. Poultry, eggs, and other livestock can carry serious pathogens, however, including *Salmonella*, *Campylobacter*, and *E. coli*, that can place consumers at risk of illness or even death (Doyle and Erickson 2006; Koluman and Dikici 2013).

In the past, a variety of antibiotics were used to reduce and control the incidence of such pathogens in agricultural animals, as well as to stimulate growth. In recent years, there has been increasing concern that widespread use of antibiotics both in livestock and humans is leading to development of pathogens that are able to resist their effects and survive. Scientists within USDA as well as those funded by USDA's NIFA, the National Institutes of Health, and others are working to find alternatives to antibiotics. Several look promising.

Selenium in its organic form can inhibit bacterial growth in the chicken gastrointestinal tract (Xu et al. 2015). Such compounds can be found in a variety of plant extracts such as those from chili peppers, garlic, cinnamon, and green teas (Diaz-

Sanchez 2015). This could reduce the need for the antibiotics which can suppress bacteria but which also can slow growth of treated birds. Prebiotic and probiotic bacteria common to the environment can produce a similar effect when fed to chickens (Patterson and Burkholder 2003).

Still other research seeks to use the birds' own immune system to develop and pass along resistance to a parasite (Yun et al. 2000). Intestinal parasites are fed to chickens with the intent to induce a protective immune response. These birds then pass some factors related to that immune response into their eggs. When powdered yolk from those eggs is fed to day-old chicks, the young birds exhibit enhanced immunity to the original parasite. These kinds of advances enhance poultry health and egg safety while reducing the use of antibiotics.

The peppers that may be in the omelet have been the subjects of a variety of scientific efforts. Peppers have considerable variation in sweet and hot flavors and aromas, and they may exhibit variation in their susceptibility to different diseases and in shelf life. Such characteristics are based on the extensive genetic variability among peppers. Breeding programs, including those taking advantage of known molecular markers in the plants' genome, have enabled USDA scientists to develop breeding lines and varieties of peppers with many desirable traits, not only for food but also as ornamentals, highly valued for their leaf shapes, growth form, vivid colors, and interesting shapes of the fruit (Stommel et al. 2014, Stommel et al. 2015; Nimakayala et al. 2016). Any omelet that contains peppers – hot, sweet, tangy, red, yellow, green, purple, disease resistant or not – carries the fruit, so to speak, of USDA research, along with the benefits of research for the eggs and most other ingredients.

Another of the ingredients in an omelet may be bacon. Pigs are among the animals that are very susceptible to foot and mouth disease, or FMD, which is caused by a virus and is extremely easily spread; indeed, as Bob Dylan, had he been an agricultural scientist, might have said, it can even be found "blowin' in the wind." The symptoms are highly unpleasant to the animals, which also include beef and dairy cattle, as well as other important livestock species. There has not been an outbreak of FMD in the United States since 1929, and USDA's Animal and Plant Health Inspection Service (APHIS) keeps stringent quarantine procedures in place to keep it out. There was a major epidemic in the United Kingdom in 2007; thousands of cases occurred, and many livestock animals had to be destroyed. The potential economic impact (in terms of farm income losses) of a similar FMD outbreak, were it to occur, in the United States has been estimated at $14 billion or more (Paarlberg et al. 2008).

There is a vaccine for FMD, but it is made with a live virus, and the US vaccine bank is dependent on overseas sources (USDA-APHIS 2007). Serious headway is being made to protect American livestock from FMD, however. USDA scientists have developed a vaccine that lacks a segment of the viral DNA that prevents it from increasing in the animal and causing infectious disease while stimulating the animal's immune system. Importantly, genetic markers in the vaccine enable discrimination of vaccinated animals from infected ones, something not possible with a vaccine produced with unmodified virus. The new vaccine can be produced safely in the United States and can be modified if new FMD strains arise. Once regulatory reviews and approvals have been obtained, the vaccine can be produced for widespread inoculation of livestock in a future FMD outbreak.

Some people may prefer poultry-based breakfast meats, such as turkey sausage. USDA made its mark on turkey production many years ago, but until the 1940s, turkeys were not an everyday item consumed on the dinner table, let alone at breakfast. Many people did not like the flavor, the birds had many pinfeathers that had to be removed, and they were so big that they often did not fit in the typical kitchen oven of the day. ARS scientists developed a small white turkey with a lot of white meat and white pin feathers that were easy to remove. The Beltsville Small White turkey became the standard at holidays and, due to the improvements, for other occasions as well. Today, not many of this kind of turkey are served, but their genetics are the foundation of most turkeys that are consumed in a variety of ways, including turkey sausage at breakfast (The Livestock Conservancy, no date).

Potatoes are served at many meals, and breakfast is no exception, as hash browns or other fried potatoes, for instance. Potatoes have long been a focus of research aimed at improving them and protecting them from disease, such as the potato late blight (*Phytophthora infestans*) pathogen, which caused the European, Irish, and Scottish Highland potato famines in the mid-1800s and led to more than a million deaths through starvation and which can still be a problem for potato farmers today. Growing potatoes remains a challenge even with the absence of disease threats, with a wide variety of factors that spell the difference between success and failure. In the state of Maine, where potato is an important crop, USDA researchers combined the results of many research projects to give producers the Potato Systems Planner Decision Support tool. The tool builds on the findings that the other crops grown in a field in rotation with the potato crop influence the various microbes in the soil, pest and pathogen populations, nutrients, and other beneficial and detrimental influences on potato plants.

The Potato Systems Planner Decision Support tool allows Maine potato growers to track and record a variety of information, such as the crops in a rotation, the kind of soil, the fertilizer used, incidence of disease in years past, and so forth, and make projections of the kinds of yields they can anticipate when they plant potatoes (Honeycutt et al. 2007; Peabody 2005).

Growers know which crops should precede and follow potatoes in their fields and when it is best to grow them. Growing potatoes every year in the same field, it turns out, is ill-advised (Peabody 2005). This decision aid can help farmers prevent crop failures and support farm income, a key feature of agricultural sustainability.

Milk and milk products are almost certain to be on many breakfast tables in some form, whether as a beverage, poured on cereal, or served as yogurt or cheese. Dairy cows and processing have been a major focus for USDA scientists for more than a century. Research on animal production and health, genetics, waste management, and product development and safety all have contributed to the dairy products found at breakfast. Nevertheless, the challenge remains to produce more milk with fewer cows and thereby reduce environmental and financial costs while increasing production.

USDA scientists and their industry partners have been particularly effective at increasing milk production. Some of this has been due to improvements in feeding (O'Brien 2016a, b). In addition, however, with new and emerging genetic and molecular technologies, further advances have been possible. Before 1994, the traits considered important in breeding highly productive dairy cows included milk produced per cow and the protein and fat content of the milk. Breeding programs depended on extensive record keeping and pedigree analysis. Selection of bulls for breeding programs often did not occur until the animals reached reproductive age and their offspring could be evaluated…an expensive endeavor. Today, through the use of molecular genetic markers and genomic analyses, breeding dairy cows has been improved tremendously. Additional traits such as animal longevity, disease resistance, conformation, ease of calving, and risk of stillbirths – all traits that may have low heritability and may have formerly been difficult or impossible to track – have become part of the breeding program. These allow animals possessing desirable genetic traits to be identified at birth rather than waiting to analyze their offspring. Such technologies provide an incremental boost to milk production and quality (McGinnis et al. 2008; Xu et al. 2014). The result is that the nation's dairies produce more milk with fewer cows and, thus, produce benefits that ripple through the economy, down to the breakfast table.

And for those 30–50 million American consumers who cannot digest milk sugar, USDA scientists conducted microbial enzyme and processing research that resulted in lactose-reduced and lactose-free dairy products (Holsinger 1997; Stanley 1995) available in nearly every grocery store across the country. Thus, dairy products are available on the breakfast tables of the lactose intolerant, like they are for everyone else.

For many people, some sort of bread item – toast, muffin, or biscuit, for example – may be their entire breakfast or at least an important part of it. If so, it's very likely that wheat was the main ingredient, a crop that has been improved and cultivated for many centuries. Despite all that effort, the diseases that have accompanied and threatened wheat for centuries are still a threat with the potential to cause serious famines in parts of the world. One of the oldest wheat diseases is the fungus that causes wheat stem rust, *Puccinia graminis f.* sp. *tritici*. Once one of the most feared of wheat pathogens, this fungus can destroy the crop on a widespread scale if environmental conditions favor the disease and plants lack resistance to it. The fungus is constantly changing through new genetic combinations, and a particularly threatening strain called Ug99 (for Uganda 1999, the place and year it was first discovered) has drawn the attention of plant pathologists and wheat breeders. It is not yet present in the United States, but USDA scientists have developed methods for detecting it quickly, and they are screening all new domestic wheat and barley breeding lines (about 2000 per year) annually in Kenya, where the disease is present and where new germplasm can be evaluated for genes that will confer resistance to it. With the aid of molecular genetic markers, the wild relatives of wheat growing in the eastern hemisphere are being screened for additional new sources of resistance genes (Olivera et al. 2012; Rahmatov et al. 2016; Yu et al. 2015). With this kind of effort, USDA scientists and their global partners continue to stay ahead of Ug99 stem rust and have kept it from entering the United States. Results of this and similar research on other diseases of our major grain crops are used worldwide in the effort to control this and other dangerous diseases and to keep bread and cereal products on the breakfast table.

Bread and other breakfast foods such as pancakes or oatmeal may be topped with honey, the most obvious manifestation of the importance of bees and other pollinators to the first meal of the day. Their importance goes far beyond just honey, however. Without pollinators, breakfast probably would be foods developed only from crops that are wind pollinated, so the meal might consist of bread, a porridge or gruel, and perhaps ale, a sort of breakfast of medieval champions. Many breakfast items, including melons, blueberries, strawberries, almonds, raisins, and coffee, come from crops that are pollinated by insects. In recent years, however, the farming, food production, and research communities have been alerted to serious problems about the health of pollinator populations.

The most notable are health declines seen in honeybees, including colony collapse disorder (CCD), which affects honeybees. In CCD-affected hives, the worker bees leave the hive seemingly in search of pollen, but do not return, so the hive gradually dies (Kaplan 2012). No single cause for honeybee decline has been identified, but most evidence suggests that a confluence of stressors is involved, including possibly pathogenic microbes, tiny parasitic mites, exposure to certain pesticides, poor nutrition in managed hives, and increasing weather variability (Goulson et al. 2015; Kaplan 2012). In 2014–2015, about 40 percent of the hives on which agriculture depends for pollination of a wide array of crops were lost (Seitz et al. 2015). While some loss each winter is expected, these levels are alarming.

These losses can be offset by beekeepers' efforts to establish new colonies in support of the demand for bees to crop pollination, and this has led to a stabilizing of the number of colonies in production in the United States. This comes at a significant cost. Reproducing new colonies to replace those that are dying is both expensive and labor intensive and, if done too frequently, leads to smaller colonies that cannot pollinate as many flowers, do not produce as much honey, and may not survive the winter.

Pollinator health and decline is of such national importance to both agriculture and natural ecosystems that Federal agencies were directed to develop a Pollinator Research Action Plan (Pollinator Health Task Force 2015) to counter continuing threats to pollinators, including honeybees. By engaging in systems research supporting Integrated Bee Management, USDA scientists are responding to the Action Plan with an emphasis on the "5 Ps":

- Parasites – Developing bees with genes that make them resistant to parasitic mites
- Pathogens – Developing and getting regulatory approval for chemicals that kill microbes that cause bee diseases
- Pests – Developing lures and traps that prevent hive invaders from getting in
- Pesticides – Determining the proper role of pesticides, balancing their ability to control pests versus the impacts on the bees themselves

- Poor nutrition – Developing the best forages and diets to keep bees healthy and resistant to other stresses

CCD and pollinator health is a very complex issue, and much has been accomplished, but we have a long way to go to understand and control it. It will require a coordinated effort of the research community, including USDA scientists.

Yet another topping for breakfast pancakes is syrup, and the most notable is maple syrup, which comes through a generations-old process from maple trees growing in forests of the Northeastern United States. A beetle native to China and Korea, the Asian longhorn beetle, ALB (*Anoplophora glabripennis*), could remove that once commonplace item (Hu et al. 2009; Smith and Wu 2008). To date, the only control methods are to detect the presence of the beetles or their larvae and to remove and destroy infected trees. Research has focused on improving methods to more rapidly detect the presence of adult beetles before they are able to infect trees. The work involves cooperation between multiple Federal and State agencies, scientists, industries (such as maple syrup producers), and the general public (through campaigns to prevent the movement of firewood that may spread the beetle larvae). All of this helps to preserve Northern hardwood forests and to keep one more item on your breakfast table.

When agricultural scientists start their research day, many of them, like many others, have a cup of coffee. For many of us, coffee is the essential part of the morning. The coffee berry borer, the most damaging pest of coffee worldwide, threatens the crop. Adults are small black beetles just a few millimeters long. The females drill into the coffee berries (often called coffee beans) and lay their eggs. The larvae that hatch from the eggs eat within the berry and destroy it (Vega et al. 2015).

Coffee production in Hawaii and Puerto Rico, two significant sources of coffee, is on small farms, but many of them are certified for organic production, so they cannot use insecticides to control such insect pests. USDA scientists are helping the farmers develop methods to manage and possibly eradicate this pest, which can destroy not only the quantity of coffee harvested but the quality of the coffee as well (Kawabata et al. 2015). Researchers have launched a multipronged attack against the beetle, including removal of berries left in the field after harvest, which can continue to host the insect; using repellents that ward off the insect; replacing coffee plants with other plants the insect cannot eat; minimizing pesticide sprays where they are allowed to minimize the development of pesticide-resistant borers; using native organisms that prey on the borers; using geographic information systems to help predict invasions based on where the insects have been found; and interfering with microbes in the insect gut that are involved with digestion, including detoxifying caffeine in the insects' diet (Ceja-Navarro et al. 2015). Implementing this variety of actions in what are termed "area-wide pest control programs" involving many growers in a large geographic zone is making headway toward eliminating this devastating pest from the islands it invaded about 10 years ago.

USDA science doesn't stop with research on the crops and livestock. It takes more than attention to what makes up the final products on the table. All of agricultural production rests on a foundation of natural resources – soil, water, and air –

that must be cared for if agricultural systems are to be sustained for future production.

Many people refer to animal manure as "waste," and if it is simply discarded, it is indeed a wasted resource. For thousands of years, farmers have used manure on their fields with great benefits for crop production. Animal manures contain nutrients that were in the feed and forage but not absorbed by the animal. Dumping these nutrients back into the air or water degrades the quality of the environment, and the nutrient value of that manure for crops is lost. That translates to lost potential income for the farmer.

USDA scientists are developing technologies to recover nutrients and more from manure produced by the hogs that are the source of the bacon on the breakfast table. In a systematic approach, bacteria are used to remove nitrogen that would be lost as ammonia gas to the atmosphere, thus reducing the amount of bioactive nitrogen pollutants released back into the environment. These can also contaminate water and lead to algal blooms and hypoxia in surface waters, as well as combine with other gases and create the unpleasant odors associated with hog farms. Controlled chemical reactions can recover phosphorus that also has adverse effects on surface waters. This technology is highly efficient: it can remove nearly 100% of the ammonia and more than 90% of the phosphorus, copper, and zinc (which hogs require but absorb poorly from their feed) and almost all of the harmful coliform bacteria that occur in swine manure and can contaminate surface water and soil. Nearly all of the solids are removed, too, and can be composted. All these nutrients and solids can be recovered and reused or marketed by the farmer. Important for everyone, the water coming out of the system meets environmental standards in the state where the research is evaluated and is considered clean enough to release back into the environment (Sharpley et al. 2006; Szogi et al. 2006; Vanotti et al. 2005). Applications for dairy operations and even municipal wastewater are being considered.

Another aspect of putting food on the breakfast table that may escape consideration by many people is how very safe their food is. Research on food safety, and the technologies and methods to keep it that way, is an important part of USDA research. One example is the use of cold plasma, which is generated by passing high-voltage electricity through air. The cloud of charged atoms, stripped of their electrons, can kill disease-causing microorganisms on the surface of foods such as fruits and nuts without damaging them (Niemira 2012). Other researchers seek new ways to detect contamination in and on foods, such as using different wavelengths of light and imaging technologies to detect microbes invisible to the naked eye on poultry or on the conveyor belts used in handling and processing a wide variety of commodities and foods (Bhunia et al. 2015, Chao 2010, Chao et al. 2007, Kim et al. 2006, Heitschmidt et al. 2007). Every American's health, and the health of many people around the world, benefits from food safety research conducted by USDA.

And then there is a product of USDA research that so many use so routinely that they forget where it originated, namely, the USDA Plant Hardiness Zone Map (http://planthardiness.ars.usda.gov/PHZMWeb/) developed by USDA and Oregon State University's PRISM Climate Group (http://www.prism.oregonstate.edu). This map helps farmers and home gardeners decide which varieties to plant for their environment to get the best-adapted vegetable varieties and other crops. For those people who grow their own, the breakfast table owes much of its bounty to good varietal selection decisions gleaned from this map, one of the most popular tools developed by USDA.

On most mornings, most of us make our way to the kitchen, eat something quickly, gulp down some orange juice and coffee, and rush out to begin our day. We rarely think about the quantity and quality of food or beverage we just consumed, or the work that goes into assuring that it is safe, or the natural resources that were essential to producing it. We just know it was there, and off we go.

On occasion, we have the pleasure of a breakfast that includes a greater portion of the diversity of foods available to us and the time to enjoy them. Taking time to survey the food on the table is an entry point to realizing a sense of all the science that goes into keeping all of it on the table: research on crop and livestock productivity and health, the quality and safety of the foods, the protection of the environment, the availability of information, technologies, and methods available to producers, processors, and consumers. It's doubtful whether the 37th Congress and President Abraham Lincoln envisioned the bounty of foods that would be available in the twenty-first century, as a result in very large part to the "practical and scientific experiments" tasked to Lincoln's new Department of Agriculture. Continuing this tradition of research and technology transfer, started more than 150 years ago, will ensure that not just Americans but people around the world will have food that is diverse, of high quality, nutritious, and safe… not just at breakfast, but at every meal of the day.

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