Proceedings of the 2011 AAAS Charles Valentine Riley Memorial Lecture

Co-sponsored by the Charles Valentine Riley Memorial Foundation in collaboration with the World Food Prize Foundation

"to promote a broader and more complete understanding of agriculture as the most basic human endeavor and...to enhance agriculture through increased scientific knowledge"

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Poppelsdorf Schloss, 1859. View from the north of Poppelsdorf mansion, built in 1854. To the right is the Agricultural Academy, built in 1851. Drawing 22 from Charles Valentine Riley's Sketchbook (1858-1860), Charles Valentine Riley Collection. Rare and Special Collections, National Agricultural Library.

Foreword

The AAAS Charles Valentine Riley Memorial Lecture is a special opportunity to highlight the important role of agricultural research as the most basic human endeavor and to enhance agriculture through increased scientific knowledge. Now in its second year, the lecture provides an important occasion to examine the role that science plays in advancing agriculture and the conservation of natural resources to ensure a secure food supply and a sustainable economy. And with the ever increasing demands of a rapidly growing population—coupled with diminishing resources—this topic could not be more relevant than it is today.

As the rising demand for food is met with factors such as the availability of fresh water and arable land, the impacts of climate change, and the need for new sources of energy, the landscape of agriculture is rapidly changing. The global science community continues to have a key role in developing solutions to effectively meet these challenges. Collaboration and cooperation among many disciplines will be essential in our planet's success to find and implement new technologies to address the looming world food shortage in sustainable and environmentally friendly ways.

Over the last couple of years, the American Association for the Advancement of Science (AAAS) has been broadening our focus on agricultural issues and the contribution we can make to these discussions. One of our priorities is to raise awareness about the importance of increased agricultural research, both in the U.S. and across the globe, so that everyone may benefit and thrive in today's world.

We continue to be grateful for the support of the Charles Valentine Riley Memorial Foundation, which made a gift in 2008—in honor of Professor Riley's legacy as a "whole picture" person with a vision for enhancing agriculture through scientific knowledge—to endow the lecture at AAAS.

Our partnership with the Riley Foundation along with our colleagues at the World Food Prize Foundation helped to ensure the success of the 2011 AAAS Charles Valentine Riley Memorial Lecture, as did the support provided by our sponsors.

I hope that you will find these proceedings useful.

Alan I. Leshner
Chief Executive Officer, AAAS and
Executive Publisher, *Science*

Acknowledgements

This year's lecturer was chosen by a distinguished Selection Committee. We would like to thank the committee members for their efforts.

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Professor and Chair in the Department of Biology, *Colorado State University*

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Member of the Board on Agriculture and Natural Resources, *National Academy of Sciences*

Ambassador Kenneth Quinn
President, *The World Food Prize Foundation*

Richard Ridgway
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Vaughan Turekian
Chief International Officer, *AAAS*

We would also like to recognize and thank the following sponsors for their generous support of this year's lecture:

Charles Valentine Riley
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About Charles Valentine Riley (1843-1895)

Charles Valentine Riley Examining an Insect.

Undated. Charles Valentine Riley Collection. Special Collections, National Agricultural Library, Beltsville, Maryland. http://www.nal.usda.gov/speccoll/.

"Professor Riley," as he was generally known, was born in Chelsea, London, England, on September 19, 1843. He attended boarding school in Dieppe, France and Bonn, Germany. Passionately fond of natural history, drawing, and painting, he collected and studied insects and sketched them in pencil and in color. At both Dieppe and Bonn, he won prizes in drawing and was encouraged to pursue art as a career.

At the age of 17, he came to the United States and settled on an Illinois farm about 50 miles from Chicago. Soon his attention was drawn to insect injuries of crops, and he sent accounts of his observations to the *Prairie Farmer.* At the age of 21, Riley moved to Chicago and worked for this leading agricultural journal as a reporter, artist, and editor of its entomological department. His writings attracted the attention of Benjamin D. Walsh, the Illinois State entomologist. It was through Walsh's influence as well as the recommendation of N .J. Coleman of *Coleman's Rural World* that Riley was appointed in the spring of 1868 to the newly created office of entomologist of the State of Missouri. From 1868 to 1877, in collaboration with T. W. Harris, B. D. Walsh, and Asa Fitch, Riley published nine annual reports as State Entomologist of Missouri, which unequivocally established his reputation as an eminent entomologist. Today, authorities agree that these nine reports constitute the foundation of modern entomology.

From 1873 to 1877, many western states and territories were invaded by grasshoppers from the Northwest. In some states their destruction of crops was so serious that it caused starvation among pioneer families. Riley studied this plague and published results in his last three Missouri annual reports and worked to bring it to the attention of Congress. In March 1877, he succeeded in securing passage of a bill creating the United States Entomological Commission, the Grasshopper Commission administered under the Director of the Geological Survey of the U. S. Department of the Interior. Riley was appointed chairman, A. S. Packard, Jr., secretary, and Cyrus Thomas, treasurer.

All this time, Riley, with the help of Otto Lugger, Theodore Pergrande, and others, was also making brilliant contributions to the knowledge of the biology of insects. Besides studying the life cycles of the 13 and 17 year cicadas, he also studied the remarkable *Yucca* moth and its pollination of the *Yucca* flower, a matter of special evolutionary interest to Charles Darwin. In addition, he conducted intensive life history studies of blister beetles and their unusual triungulin larvae, and the caprification of the fig.

In the spring of 1878, Townend Glover retired as entomologist to the U. S. Department of Agriculture and Riley was appointed his successor. After a year in this position, Riley resigned owing to a disagreement with the Commissioner of Agriculture over Riley's practice of making independent political contacts; he then continued the work of the U. S. Entomological Commission with others, from his home. Two years later, after the inauguration of President James A. Garfield in 1881, Riley was reappointed and remained chief of the Federal Entomological Service until June 1894, when the Service was renamed the Division of Entomology of the U.S. Department of Agriculture. In 1882, Riley gave part of his insect collection to the U. S. National Museum, now The Smithsonian Institution, at which time he was made honorary curator of insects. In 1885, he was appointed assistant curator of the Museum, thus becoming the Museum's first curator of insects, whereupon he gave the Museum his entire insect collection consisting of 115,000 mounted specimens (representing 20,000 species), 2,800 vials, and 3,000 slides of specimens mounted in Canadian balsam.

One of Riley's greatest triumphs while Chief of the Federal Entomological Service was his initiation of efforts to collect parasites and predators of the cottony cushion scale, which was destroying the citrus industry in California. In 1888, he sent Albert Koebele to Australia to collect natural enemies of the scale. A beetle, *Vedalia cardinalis,* now *Rodolia cardinalis,* was introduced into California and significantly reduced populations of the cottony cushion scale. This effort gave great impetus to the study of biological control for the reduction of injurious pests and established Charles Valentine Riley as the "Father of the Biological Control."

A prolific writer and artist, Riley authored over 2,400 publications. He also published two journals, the *American Entomologist* (1868-80) and *Insect Life* (1889-94). Riley received many honors during his lifetime. He was decorated by the French Government for his work on the grapevine *Phylloxera.* He received honorary degrees from Kansas State University and the University of Missouri. He was an honorary member of the Entomological Society of London and founder and first president of the Entomological Society of Washington. He and Dr. L. O. Howard, Riley's assistant in the Federal Entomological Service, were among the founders of the American Association of Economic Entomologists, which became part of Entomological Society of America in 1953.

Tragically, on September 14, 1895 Riley's life was cut short by a fatal bicycle accident. As he was riding rapidly down a hill, the bicycle wheel struck a granite paving block dropped by a wagon. He catapulted to the pavement and fractured his skull. He was carried home on a wagon and never regained consciousness. He died at his home the same day at the age of 52, leaving his wife with six children.

Lecture and Panel Discussion Summary

The 2011 Charles Valentine Riley Memorial Lecturer, Dr. Pamela C. Ronald, began her remarks with the question: "How do we feed the growing population without further destroying the environment?" With limits on the amount of arable farmland and water available, feeding billions of humans will require greatly increasing the productivity of farming while minimizing its detrimental environmental impact, she said.

"Agriculture needs our collective help and all appropriate tools if we are to feed the growing population in an ecological manner," began Ronald, a plant genetics expert noted for her work in engineering rice for resistance to disease and tolerance to flooding. She is also co-author of the book *Tomorrow's Table: Organic Farming, Genetics, and the Future of Food*.

In her remarks, Ronald said world population is projected to surpass 9 billion by 2050. To feed so many without increasing plant yields, agricultural experts estimate the world would have to double its croplands by 2050, she said, which is not possible because most arable land is already in use and much of the remaining land is marginal for farming. Compounding these problems is erosion, which over the past 40 years has rendered 30 percent of arable land unproductive.

Another challenge is fresh water. She noted that half the world's wetlands have disappeared, groundwater aquifers are being used at an unsustainable rate, and water tables in parts of Mexico, India, China, North Africa, and the United States are declining as much as one meter a year as demand continues to rise.

"Seventy percent of the world's fresh water is already used for agriculture," Ronald said. "This means that increased food production must largely take place on the same land area while using less water."

To combat these issues, Dr. Ronald offered that increased use of new seed and plant varieties, including those developed through genetic engineering, can help increase productivity while limiting negative environmental, economic, and social impacts of agriculture. However, she countered that planting higher-yielding, genetically improved seed that require less water and insecticides is not sufficient to address all agricultural challenges. Only by combining the use of improved seed with ecologically-based agricultural practices can sustainability be maximized, she said.

"The key point is that no matter how powerful the seed technology... the seed must still be integrated with other strategies to manage the diverse spectrum of diseases and pests that attack a crop."

Ronald added that to be successful, agricultural policies should be based on scientific evidence. "After 14 years of cultivation and a cumulative total of nearly 2 billion acres planted... not a single instance of harm to human health or the environment has resulted from commercialization of genetically engineered crops." She noted that the world's leading experts—represented by the Indian, Chinese, Mexican, Brazilian, French, British, and American academies of science—have concluded that the genetically engineered crops currently on the market are safe to eat and safe for the environment. And that while all methods of breeding introduce genetic changes with risk of unintended consequences, these risks are similar for conventional breeding and genetic engineering. For these reasons, she said, there is no scientific basis for ruling out genetic engineering as a tool for crop improvement.

Ronald said many more countries are exploring the use of genetically engineered crops, noting there are currently 30 commercialized genetically engineered crops cultivated worldwide. The number will grow to more than 120 by 2015. Half will come from national technology providers in Asia and Latin America designed for domestic markets.

She stated that the polarizing debates on seed technologies versus farming practices were distracting from the key challenge—a healthy and productive agricultural system. Furthermore, she believes that discussions about agriculture must be framed in the context of the environmental, economic, and social impacts of agriculture —the three pillars of sustainable agriculture.

She concluded her remarks by saying that rather than focusing on how a seed variety was developed, we must ask what most enhances local food security and can provide safe, abundant, and nutritious food to consumers.

Panel Discussion

Nina V. Fedoroff, Ph.D.

AAAS President; Willaman Professor of the Life Sciences and Evan Pugh Professor, Huck Institutes of the Life Sciences, Pennsylvania State University; and Distinguished Visiting Professor, King Abdullah University of Science and Technology

Nina Fedoroff, who moderated the panel discussion said farming will need to double productivity in the coming decades, while reducing farming's ecological impact. This will require many innovations in crop improvement, as well as better water management and more efficient nutrient use. She added that regulation of plants, animals, and other agricultural products should be based on their properties and not the method by which they are produced.

L. Val Giddings, Ph.D.
Senior Fellow, Innovation and Research and Development, Information Technology and Innovation Foundation

L. Val Giddings joined the discussion by saying that resistance to genetically engineered crops is beginning to abate in Europe, where constraints and barriers to their use have been strongest. As results come in from more studies showing no evidence of greater risk from genetically engineered crops, he said, attitudes are changing. He noted that "One of the most important barriers to overcome is dogma...The people will not tolerate being kept hungry."

John D. Hardin, Jr.
Owner, Hardin Farms

John D. Hardin, Jr. said another concern about using genetically engineered and hybrid seed is cost and availability. He noted that currently, a small number of companies now control such seed sources. Because genetically engineered seed must clear additional regulatory and legal requirements (compared to hybrid and other seed), it is complicated and expensive to bring these seeds to market, Hardin said, limiting access to large companies that can afford to pay the additional costs. He also added that farming is more than just growing food. Agriculture means managing an ecosystem, he said, learning how to limit use of fertilizers and pesticides while adopting sustainable methods, such as limiting tilling or plowing of the soil to decrease erosion and using cover crops instead of artificial fertilizer to enrich soil.

Mark Rosegrant, Ph.D.
Director, Environment and Production Technology Division, International Food Policy Research Institute

Mark Rosegrant contended there has to be more investment in agricultural research, particularly in populous developing countries, so that more food can be grown locally. He said these steps will cut the need and expense of importing so much food and generate income in rural areas. And that this effort should include investment in rural infrastructure development to improve access to markets and resources for local farmers.

Michael T. Clegg, Ph.D.
Donald Bren Professor of Biological Sciences, Ecology & Evolutionary Biology, University of California, Irvine; and Foreign Secretary, U.S. National Academy of Sciences

Michael T. Clegg added that the current agricultural systems not only need to be made more efficient but more adaptable to changing conditions. He said that agricultural production increasingly will face new problems, including impending climate change that will result not only in rising waters in coastal areas but also shifts in growing seasons and different rainfall and drought patterns in many areas.

"Tomorrow's Table: Organic Farming, Genetics and the Future of Food"

Pamela C. Ronald
Professor of Plant Pathology, University of California, Davis

Thank you for the kind introduction and to the Committee for selecting me to deliver the lecture today. I am honored to celebrate the work of Charles Valentine Riley, and pleased to help promote the goal of the Riley Memorial Foundation "to enhance agriculture through increased scientific knowledge." I am also delighted to "advance science and serve society," a key mission of the American Association for the Advancement of Science. Finally I would like to thank the World Food Prize Foundation for their work honoring individuals who have worked successfully to advance global food security. I extend my heartfelt congratulations to the winners of the 2011 World Food Prize, which were announced today.

Riley was an early agroecologist and a biotechnologist. He not only developed innovative science-based approaches to combat specific agricultural challenges, he showed that both agroecology and biotechnology could profoundly benefit agriculture. Given the demand that will be placed on agriculture in coming decades, we need to build on Riley's legacy as never before. We will need to employ modern genetic tools and the most effective science-based farming practices to address a critical challenge of our time: How do we feed the growing population without further destroying the environment?

Millions of lives depend upon the extent to which agricultural science can keep pace with the growing global population, changing climate, and shrinking environmental resources.

My husband, Raoul Adamchak, and I often discuss this question. Raoul has been an organic farmer for thirty years, part of the time as a partner in a private 150-acre organic vegetable farm. He served as a member, inspector and president of the California Certified Organic Farmers Board of Directors. He now teaches organic production practices and manages a five-acre market garden at the University of California, Davis Student Farm.

You may think that a geneticist and an organic farmer represent polar opposites of the agricultural industry. You may even think that we don't talk to each other. But we do—and it is not difficult because we both have the same goal: an ecologically based system of agriculture.

Still, over the years, many of our friends, family, and colleagues have asked us how the process of genetic engineering will affect the environment and our food. Many of our scientific colleagues have asked us if organic farming can produce sufficient food to feed the world.

In response to these questions, Raoul and I wrote *Tomorrow's Table: Organic Farming, Genetics and the Future of Food*. Our intention was to give readers a better understanding of what geneticists and organic farmers actually do and also to help readers distinguish between fact and fiction in the debate about organic farming and crop genetic engineering. Our book was guided by our belief that the polarizing debates on seed technologies versus farming practices were distracting from the key challenge—a healthy and productive agricultural system.

Before we talk about the future of food, we need to first look at the agriculture that we have today. We face looming food shortages. World economic and agricultural leaders have projected that the human population will surpass 9 billion by 2050, and 10 billion by the turn of the century. And they have forecast that we must double or even triple food production to meet demand. To accomplish this goal without increasing yield would necessitate a near doubling of the world's cropland area by 2050. But it is no longer possible to feed more people simply by expanding farms to undeveloped land. The amount of arable land is limited and what is left is being lost to urbanization and environmental degradation. Farmers are so pressed for space in many parts of the world that much of the land now being farmed is marginal, such as the steep hills of Ecuador.

Another challenge facing agriculture is erosion, which occurs when there is insufficient vegetation to hold soil in place. At a time when we need more farm land, we have less, due to erosion. As rain falls, channels form that transport soil away. About 60 percent of soil that is washed away ends up in rivers, streams and lakes. The soil also carries agricultural fertilizers and pesticides that become food for aquatic organisms. Bacteria thrive off of excessive organic matter and use oxygen, the same oxygen that fish, crabs and other sea creatures rely on for life. This leads to dead zones of highly turbid waters that are devoid of sea animals. As a result of erosion over the past 40 years, 30 percent of the world's arable land has become unproductive. And because soil is formed slowly, it is essentially a finite resource.

Our fresh water systems are also under severe strain. Many rivers no longer flow all the way to the sea; 50 percent of the world's wetlands have disappeared, and major groundwater aquifers are being mined unsustainably. Water tables in parts of Mexico, India, China, and North Africa are declining by as much as 1 m per year. The fresh water available per person has decreased fourfold in the past 60 years and demand is expected to increase

by 30 percent by 2030. Seventy percent of the world's fresh water is already used for agriculture. This means that increased food production must largely take place on the same land area while using less water.

Advances in agricultural productivity have partly relied on combating pests with pesticides. But pesticides can be toxic to farm workers. Long-term health impacts have been associated with exposure to some pesticides. These include increased risk of prostate cancer, Parkinson's and other diseases. The World Health Organization has estimated that between 3.5 and 5 million people globally suffer acute pesticide poisoning every year, resulting in 300,000 deaths. More than half the deaths occur in less developed countries where pesticides are often not used safely.

Compounding the challenges facing agricultural production are the predicted effects of climate change. In the past 10 years, Australia has undergone two record-breaking droughts, which crippled wheat production, and Russia banned wheat exports last year because of drought.

As the sea level rises and glaciers melt, low-lying croplands will be submerged and river systems will experience shorter and more intense seasonal flows, as well as more flooding. These losses disproportionately affect the poorest farmers in the world. For example, the people of Bangladesh get about two-thirds of their total calories from rice. Large areas of Bangladesh already flood on an annual basis and are likely to be submerged completely in the future, leading to a substantial loss of agricultural land area. Yield is important not only for farmer profit and nutrition, it is critical for preserving wilderness. When yield is low, farmers expand to undeveloped areas and pristine ecosystems to grow food. Such expansion of farming occurs all over the world, destroying vast quantities of wilderness and wildlife each year. Today, 40 percent of the Earth's surface has been cleared for farming—an area the size of South America.

In my home in the California Central Valley, 90 percent of our vernal pools have been lost due to expanding agriculture and urban environments. Such pools are spectacular. They fill up each rainy season and serve as a home for rare species of fairy shrimp, salamanders, freshwater insects, and frogs. As the pools slowly dry out each spring, brightly colored concentric rings of flowers appear, including goldfields, purple owl clovers, and blue lupines. Such treasures need to be protected. As the demand for food increases, a key challenge will be to minimize the impact of food production on what remains of wild nature.

Imagine what the earth will look like in 40 years if we do not change our farming practices and use food more efficiently. If we do nothing, vast amounts of wilderness will be lost, millions of birds and billions of beneficial insects will die, farm workers will be at increased risk for disease, the public will lose billions of dollars as a consequence of environmental degradation. And still, many people will be hungry.

This brings us back to the key question: How can we feed the world without destroying it?

Raoul and I believe that the discussions about agriculture must be framed in the context of the environmental, economic, and social impacts of agriculture—the three pillars of sustainable agriculture. Rather than focusing on how a seed variety was developed, we must ask what most enhances local food security and can provide safe, abundant and nutritious food to consumers. We must ask if rural communities can thrive and if farmers can make a profit. We must be sure that consumers can afford the food. And finally we must minimize environmental degradation. This includes conserving land and water, enhancing farm biodiversity and soil fertility, reducing erosion and minimizing harmful inputs.

Now I would like to turn to specific examples of agricultural practices and technologies that have advanced the sustainability of our farms. First let's consider the power of farming practices. Organic farming began as a response to the overuse of pesticides and fertilizers. In the U.S., the USDA certifies farms as organic based on specific criteria. The farms must have three years with no prohibited material, such as synthetic fertilizers and synthetic pesticides, and be inspected on an annual basis by a USDA accredited certifier. All modern seed varieties are allowed except for genetically engineered seed. Organic agriculture relies on integrated management to control pests and disease. This includes crop rotation to minimize buildup of pests that attack a specific crop, genetically improved seed that are resistant to disease and non-synthetic pesticides. It also includes the integration of beneficial insects that prey on pests that attack crops.

The basis of much of this work originated with Charles Valentine Riley who pioneered the use of biological control by introducing a beetle that was the natural enemy of an insect that was damaging the California citrus industry.

Organic farming fosters soil fertility through use of compost and fertilizers made from agricultural by-products rather than synthetic nitrogen fertilizers. This reduces energy use on the farm because synthesis of nitrogen fertilizers requires massive amounts of the energy to generate-an estimated one percent of global energy consumption is used for this purpose.

Organic farmers build soil and add nitrogen through use of cover crops. These are plants that can fix atmospheric nitrogen through interactions with symbiotic bacteria. Clearly, organic production practices can be an important component of sustainable agriculture.

But some organic practices are not sustainable. Certain organic pesticides, such as rotenone or copper sulfate, are toxic to humans and other animals at high concentrations. While organic crop yields can be compa-

rable to those of conventional farms in some situations for some key crops such as rice, yields are often lower on organic farms. The higher prices of organic produce reduce availability to low-income consumers, thus falling short of one of the goals of sustainable agriculture.

Some pests and diseases are difficult to address using organic or conventional methods and can have devastating consequences. We need look back just 150 years to the Irish potato famine, caused by the late blight pathogen, to see how agriculture has dramatically changed the course of history. Between 1845 and 1852, approximately 1 million people died and 1 million more emigrated from Ireland to flee starvation resulting from this agricultural disaster. One of these emigrants was Falmouth Kearney, the son of the village shoemaker, who in 1850 emigrated at the age of 19 to New York. He was President Obama's great-great-great grandfather. Patrick Kennedy, the great-great-grandfather of John, Bobby and Teddy, also left Ireland due to the impacts of the famine.

This brings us to a key technology that has advanced the sustainability of our farms; genetically improved seed. Historically, advances in plant genetics have provided the knowledge and technologies needed to address the challenges of pests, disease and environmental stress in a cost-effective and efficient manner. This is because seeds carry traits critical for tolerance to stress and resistance to disease. What seed a farmer sows has a huge impact on the yield.

Our ancestors knew this.

Plants were first genetically altered through primitive domestication, nearly 13,000 years ago. Grafting of two different species was one of the earliest examples of biotechnology, and Charles Valentine Riley was among the first to employ this approach. In the late 19th century *Phylloxera,* an aphid-like insect, destroyed most of the vineyards in Europe, most notably in France. Some estimates hold that between two-thirds and nine-tenths of all European vineyards were destroyed. Riley grafted the French grape to the rootstock of American grapes, which were resistant to *Phylloxera*. This effort helped save the French wine industry.

After Gregor Mendel hypothesized that "genes" were the basis of heredity in 1866, plant breeding accelerated. Breeders transferred genes within species using hand pollination but also between species, such as in the crossing of wheat and rye to produce triticale.

In 1900, the discovery of hybrid production led to dramatic increases in yield. In 1927, breeders experimented with X-rays and chemicals to induce random mutations into the DNA of crop varieties. In 1973, recombinant DNA was discovered, allowing the precise introduction of genes from one species into another. The first genetically engineered (GE) crop was approved in 1993. Today over 1 billion acres of GE crops have been planted.

The results of these centuries of breeding are crops with higher yields, better flavor and enhanced nutrition. For example, the ancient ancestor of modern-day corn, called teosinte, comes from a plant that doesn't look anything like a modern corn plant. Teosinte produces 10 or 20 seeds per plant. It takes a hammer to break open the seed to expose the nutritious kernel. In contrast, modern hybrid corn produces several ears, each bearing in excess of 1,000 seeds. If we had to depend on teosinte for our nutrition, we would have to cultivate hundreds, if not thousands, of more acres just to get the same amount of nourishment.

Since Mendel's time we have seen dramatic advancements in plant genetics. In 2000, the first plant genome was sequenced after 7 years at a cost of $70 million. This year, the same project is expected to take 2-3 minutes and cost $99. Not only do we have the *Arabidopsis* genome, but we have rice and corn genomes and many other genomes as well. The challenge today is to use this knowledge of plant genetics to develop new varieties that will enhance sustainable agriculture. And this is where the National Institutes of Health, the USDA, the USAID, and the National Science Foundation can play a critical role in supporting the necessary publicly funded research.

We also need to support the regulatory agencies that assess the safety and effectiveness of our food and new crop varieties. Policies developed to address the challenges of food security must be anchored in the highest quality peer-reviewed science. The world's leading experts—represented by the Indian, Chinese, Mexican, Brazilian, French, British and American academies of science have concluded that the GE crops currently on the market are safe to eat and safe for the environment. After 14 years of cultivation and a cumulative total of nearly 2 billion acres planted, not a single instance of harm to human health or the environment has resulted from commercialization of genetically engineered crops.

All methods of breeding introduce genetic changes with risk of unintended consequences. These risks are similar for conventional breeding and genetic engineering. For this reason, there is no scientific basis for ruling out GE as a tool for crop improvement. This is not to say that every new crop variety will be as benign and beneficial as the crops currently on the market. Nor is genetic engineering always the most appropriate technology. Each new variety must be examined on a case-by-case basis.

I will finish with a few examples of modern seed varieties that have had tremendous positive impacts on sustainable agriculture.

The first is papaya. Like humans, plants are also vulnerable to viral disease. In the 1950s, the entire papaya production on the island of Oahu was decimated by papaya ringspot virus. Because there was no way to control this virus, farmers moved their papaya production to the

island of Hawaii where the virus was not yet present. In 1992, the virus had invaded the papaya orchards where 95 percent of the state's papaya was grown. By 1995 the disease was widespread, creating a crisis for Hawaiian papaya farmers. Anticipating the outbreak, Dennis Gonsalves, a local Hawaiian and a USDA scientist, initiated a genetic strategy to control the disease. Gonsalves' group engineered papaya to carry a transgene from a mild strain of papaya ringspot virus. Conceptually similar (although mechanistically different) to human vaccinations against polio or small pox, this treatment "immunized" the papaya plant against further infection. The publicly funded, freely distributed genetically engineered papaya yielded 20 times more papaya than the non-genetically engineered variety.

This is a case where genetic engineering was the most appropriate technology to address a serious agricultural problem. Even today, there is still no conventional or organic method available to control the virus. Like Riley, Gonsalves' use of biotechnology—mixing genes from different species—saved an industry. Today, 80–90 percent of Hawaiian papaya is genetically engineered.

The second example is cotton bollworm. The Environmental Protection Agency considers seven of the top 15 insecticides used on cotton in 2000 in the United States as "possible" or "known" human carcinogens. The bacterium *Bacillus thuringiensis* produces an insecticidal protein called Bt that kills pests but is nontoxic to mammals, birds, fish and humans. Bt toxins in sprayable formulations were used for insect control long before Bt crops were developed and are still used extensively by organic growers and others. In the 1990s, Monsanto introduced a cotton variety that expressed the Bt protein. Fifteen years of peer-reviewed studies have allowed researchers to evaluate the efficacy and sustainability of this approach. In Arizona, farmers growing Bt cotton cut their insecticide use in half while maintaining the same yield as their neighbors. Insect biodiversity increased as measured by the diversity of beetles and ants in the field.

Chinese and Indian farmers growing Bt cotton or rice were able to dramatically reduce their use of insecticides. In a study of genetically engineered rice in China, these reductions were accompanied by a decrease in insecticide-poisonings. Despite these successes in reducing pesticide use, most farmers know that developing more productive seeds is just one element of an effective strategy. The key point is that no matter how powerful the seed technology, the seed must still be integrated with other strategies to manage the diverse spectrum of diseases and pests that attack a crop. Bt cotton in China is a case in point. Although Bt cotton has effectively controlled cotton bollworm, a pest called mirids not targeted by Bt has become prevalent. These results confirm the need to integrate Bt crops with other pest control tactics.

As the acreage of organic production and GE crops grows, it will be increasingly necessary to move past the discussions of GE and organic as being "good" or "bad" and develop practical and mutually agreeable policies of coexistence to make the agricultural system workable for all growers. Good communication and common sense are key to dealing with pollen flow. These principles apply to all crops—GE, organic, and conventional.

I would like to finish with a brief overview of my research.

Rice is a staple food for more than half the worlds' people. Three-quarters of the world's poorest people get their food and income by farming small plots of land. The availability of seeds that carry traits for disease resistance or stress tolerance can have a large impact on yield. In the U.S. and Europe most conventional and organic farmers buy their seed from for-profit seed companies. In contrast, rice farmers generally produce their own seed on the farm. For more than 100 years, breeders have introduced genes for resistance as the most economic and effective method for controlling disease. Today, virtually everything we eat carries these resistance genes.

In the 1990s, an avalanche of genetic experiments led to the isolation of the first resistance genes. This was an exciting time because scientists could finally begin to understand how these genes functioned.

In 1995, my laboratory isolated a gene that confers resistance to bacterial blight disease, the most serious bacterial disease of rice in Asia and Africa. Genetically engineered rice plants carrying this gene were completely resistant to the bacteria. After two weeks, lesions developed only on the rice plants lacking the resistance gene. This research, supported by the NIH, is not only important for plant biology, we now know that humans carry a similar set of genes to confer immunity to infection.

For the last 16 years, I have also worked on understanding the genetic basis of tolerance to flooding. One quarter of the global rice cropland is prone to flooding. These losses disproportionately affect the poorest farmers in the world. Some 2.2 billion rice consumers live in these flood-prone areas; 75 million of these people live on less than $1 per day. In Bangladesh and India, 4 million tons of rice, enough to feed 30 million people, is lost each year to flooding. Nearly all rice varieties die within one week of submergence.

More than 50 years ago, breeders discovered an unusual variety of rice from Eastern India. This variety has poor grain and yield qualities but is unusual in its ability to endure complete submergence for approximately 14 days. In the 1980s, using conventional breeding, breeders tried to introduce this flood-tolerant trait into rice varieties that had high yields, but they unintentionally dragged in undesirable traits along with it. The new varieties were therefore unacceptable to farmers.

In 1996, David Mackill, a USDA rice breeder at the University California, Davis and I received a grant from the USDA to isolate the gene for submergence. We hoped

that we could use my expertise in gene isolation to identify the gene for submergence tolerance and then use his skill as a breeder to more precisely introduce the gene into locally adapted varieties. In 2003, my lab identified a candidate gene that rapidly responded to days of submergence. To prove that we had the correct gene, we transformed it into rice varieties that normally die after 16 days submergence. The GE variety (Sub1) was tolerant. Mackill, who had moved to the International Rice Research Institute, used this genetic information to carry out a precision breeding approach to introduce this gene into varieties favored by farmers. After a 17-day flood, 95 percent of the Sub1 plants survived, whereas most of the conventional plants died. He then led three years of field tests in Bangladesh and India. The farmers found that the Sub1 varieties were highly tolerant of flooding, yielding a three to five fold more than conventional varieties.

In 2004, our research team was joined by a talented plant physiologist, Julia Bailey- Serres, from the University of California, Riverside. In 2008, our teams traveled to India and Bangladesh to meet the growers. One of the farmers told us that they had more food for their family and had extra to sell. Another told us that she was surprised and happy that the rice survived the flood.

This year, with funding from the Bill and Melinda Gates Foundation, Sub1 rice is expected to reach over one million farmers in five countries. The development of submergence tolerant rice, through gene cloning and precision breeding, demonstrates the power of genetics to improve tolerance to environmental stresses such as flooding. The Sub1 project also demonstrates the importance of public funding for projects involving collaborations between geneticists and breeders that are aimed at the needs of smallholder farmers.

Today, more and more countries are exploring the use of GE for a greater variety of crops. Currently there are 30 commercialized GE crops cultivated worldwide. By 2015 there will be over 120. Half will come from national technology providers in Asia and Latin America designed for domestic markets.

Golden rice, a genetically engineered variety with enhanced provitamin A content, will be released in the next one to two years. In India, 70,000 children are lost every year to vitamin A deficiency. It is predicted that one cup of golden rice per day will reduce cases of blindness and the deaths of 100,000 young children each year. Release of Bt eggplant in India and the Philippines is expected to greatly reduce the use of insecticides. The USDA has released a plum resistant to a potentially devastating virus. Soon to follow are drought-tolerant wheat, insect-resistant potato and disease-resistant bananas.

Agriculture needs our collective help and all appropriate tools if we are to feed the growing population in an ecological manner. We need everyone at the table. This includes breeders, organic farmers, seed companies, geneticists, consumers and students. We need foundations, the UN, the World Bank, government agencies, and others to intensify their support for plant science-based research. We need all of you in Washington to support research that will result in genetically improved seed and ecologically-based farming practices that are good for the environment and good for consumers.

Participant Bios

Pamela C. Ronald, Ph.D., is a Professor in the Department of Plant Pathology at the University of California, Davis.

Dr. Ronald conducts internationally acclaimed research on the role genes play in plants' response to the environment. Her laboratory has genetically engineered rice for resistance to diseases and flooding. Dr. Ronald is co-author of the book *Tomorrow's Table: Organic Farming, Genetics, and the Future of Food,* which examines the contributions of genetically engineered crops and organic farming to sustainable agriculture. In 2011, she was named as one of the 100 Most Creative People In Business by *Fast Company* magazine.

She as is an elected Fellow of the American Association for the Advancement of Science. She was awarded Fulbright (1984), Guggenheim (2000), and Japan Society for the Promotion of Science (2008) Fellowships. In 2008, she and her colleagues were recipients of the USDA National Research Initiative Discovery Award for their work on submergence tolerant rice. And in 2009, they were finalists for the World Technology Award for Environment. Also that same year, Dr. Ronald received the National Association of Science Writers Science in Society Journalism Award and was nominated for the Biotech Humanitarian Award.

Nina V. Fedoroff, Ph.D., is a Distinguished Visiting Professor of the King Abdullah University of Science and Technology in Saudi Arabia and a member of the external faculty of the Santa Fe Institute. She also holds both the Evan Pugh and Willaman Life Sciences professorships at Pennsylvania State University. She is the current President of the AAAS Board of Directors.

Prior to her current positions, she served as Science and Technology Adviser to the Secretary of State and to the Administrator of USAID. Before that, she was director of both the Life Science Consortium and the Biotechnology Institute at Pennsylvania State University. She has also held positions at the Carnegie Institution of Washington, Johns Hopkins University, and the University of California, Los Angeles. Her research interests include plant stress response, hormone signaling, transposable elements, and epigenetic mechanisms.

Dr. Fedoroff is a member of the National Academy of Sciences, the American Academy of Arts and Sciences, and the Phi Beta Kappa and Sigma Xi honorary societies. She also serves on the Board of Trustees of the Library of Alexandria, Egypt, and the Board of Governors at the Institute for Complex Adaptive Matter of the Los Alamos Laboratory. Her recent honors include the Arents Pioneer Medal from Syracuse University in 2003, an Honorary Doctorate from Rockefeller University in 2008, and the Public Service Award from the American Society of Plant Biologists in 2010. Dr. Fedoroff received the 2006 National Medal of Science from U.S. President George W. Bush for her research in the fields of plant genetics, plant responses to environmental stress, and genetically modified crops.

Michael T. Clegg, Ph.D., is currently the Donald Bren Professor of Biological Sciences at the University of California, Irvine. He has also served as Foreign Secretary of the U.S. National Academy of Sciences since 2002.

Before joining the faculty at UC Irvine in 2004, he was founding Director of the Genomics Institute at the University of California, Riverside from 2000 to 2004. Before that, he was Professor of Genetics at UC Riverside, where he also served as Dean of the College of Natural and Agricultural Sciences from 1994 to 2000.

Dr. Clegg's research is in population genetics and molecular evolution. His early work in population genetics focused on the dynamical behavior of linked systems of genes in plant and *Drosophila* populations. During this period, he also contributed to the theoretical study of multilocus systems employing computer simulations together with the analysis of mathematical models. Later he helped pioneer the comparative analysis of choloroplast DNA variation as a tool for the reconstruction of plant phylogenies. His current work is concerned with the comparative genomics of plant gene families, the molecular evolution of genes in the flavonoid biosynthetic pathway, the use of coalescent models to study crop plant

domestication and the application of molecular markers to avocado improvement.

Dr. Clegg has received numerous awards including a Guggenheim Fellowship (1981) and the Darwin Prize of Edinburgh University (1995). He was elected to membership in the U.S. National Academy of Sciences in 1990 and he was elected a Fellow of the American Academy of Arts and Sciences in 1992. He has also served as President of the American Genetic Association (1987), President of the International Society for Molecular Biology & Evolution (2002) and Chair of the Section on Agriculture, Food and Natural Resources of the American Association for the Advancement of Science (2003).

L. Val Giddings, Ph.D., is a Senior Fellow at the Information Technology and Innovation Foundation.

After nearly three decades in science and regulatory policy relating to biotechnology innovations in agriculture and biomedicine, he brings intellectual leadership to the examination of the constraints inhibiting innovations in these areas, and devising remedies to those constraints. He is also President and CEO of PrometheusAB, Inc., providing consulting services in regulatory compliance, media, and strategic planning to governments, multilateral organizations, and industry clients in the U.S. and around the world.

Before founding PrometheusAB, Dr. Giddings served for eight years as Vice President for Food & Agriculture of the Biotechnology Industry Organization (BIO). At BIO, he built a highly regarded program representing global biotech companies in policy, regulation, media and international affairs. Before joining BIO he spent eight years with the biotech products regulatory division of USDA Animal and Plant Health Inspection Service (APHIS). While with APHIS he was International Team Leader and Branch Chief for Science & Policy Coordination. During this time, he gained substantial international experience, serving on the U.S. delegations to negotiate the biodiversity treaty and to the Earth Summit in Rio de Janeiro. Dr. Giddings arrived in Washington in 1984 to join the Congressional Office of Technology Assessment, where he worked on studies related to biotechnology, the environment, and regulatory policy.

He has also served as an expert consultant to the United Nations Environment Programme, the World Bank, USDA, USAID, and numerous companies, organizations and governments around the world.

John Hardin, Jr., owns and operates Hardin Farms, a grain and pork operation located 25 miles west of Indianapolis, Indiana. The operation raises identity preserved corn and soybean varieties for use in the food industry. About two-thirds of the hogs produced are sold via a marketing agreement for pork exported to Japan.

He is a trustee of Purdue University and the Farm Foundation, a board member of the American Farmland Trust, and a member of the Design Team for the United Nations Foundation Sustainable Solutions from the Land project. Mr. Hardin also participates in the Clean Energy Dialogue for 25 by 25. He is a past president of the National Pork Producers Council and a former chairman of the United States Meat Export Federation.

Mark W. Rosegrant, Ph.D., is Director of the Environment and Production Technology Division at the International Food Policy Research Institute (IFPRI).

Dr. Rosegrant has over 30 years of experience in research and policy analysis in agriculture and economic development, with an emphasis on water resources and other critical natural resource and agricultural policy issues as they impact food security, rural livelihoods and environmental sustainability. He developed IFPRI's International Model for Policy Analysis of Agricultural Commodities and Trade (IMPACT), which has become a standard for projections and scenarios for global and regional food demand, supply, trade and prices; and IMPACT-WATER, which integrates a detailed water supply and demand model with the food model. He currently directs research on climate change, water resources, sustainable land management, genetic resources and biotechnology, and agriculture and energy.

Dr. Rosegrant is the author or editor of seven books and over 100 refereed papers in agricultural economics, water resources and food policy analysis. He has won numerous awards, is a Fellow of the American Association for the Advancement of Science, and in 2007 was elected Distinguished Fellow of the American Agricultural Economics Association.

Federal Food, Nutrition, Agriculture, and Natural Resource Sciences Funding Update

Patrick Clemins, Director, R&D Budget and Policy Program
American Association for the Advancement of Science

Federal Food, Nutrition, Agriculture, and Natural Resource Science Investments

(budget authority in millions of dollars)

	FY 2010 Actual	FY 2011 Estimate	Change FY 10-11 Amount	Change FY 10-11 Percent	FY 2012 Budget	**FY 2012 House**	Change Request Amount	Change Request Percent	Change FY 11-12 Amount	Change FY 11-12 Percent
Selected USDA Programs										
Agricultural Research Service (ARS)	1,251	1,133	-117	-9.4%	1,138	**988**	-150	-13.2%	-146	-12.9%
Natl Inst of Food & Agri (NIFA)	1,343	1,215	-128	-9.6%	1,205	**1,012**	-193	-16.0%	-203	-16.7%
Agri & Food Research Init (AFRI)	262	264	2	0.8%	325	**228**	-97	-29.9%	-37	-13.9%
Forest Service	5,297	5,085	-212	-4.0%	5,125	**4,713**	-412	-8.0%	-372	-7.3%
Forest and Rangeland Research	341	307	-34	-10.1%	296	**277**	-18	-6.3%	-29	-9.6%
U.S. Dept of Agriculture R&D	2,611	2,337	-274	-10.5%	2,343	**1,976**	-367	-15.7%	-361	-15.5%
Other Related Agencies										
National Institutes of Health	31,243	30,925	-318	-1.0%	31,987	- -	- -	- -	- -	- -
National Science Foundation	6,873	6,860	-13	-0.2%	7,767	**6,860**	-907	-11.7%	0	0.0%
Dept of Energy - Office of Science	4,964	4,843	-121	-2.4%	5,416	**4,800**	-616	-11.4%	-43	-0.9%

Source: AAAS estimates based on OMB R&D data, agency budget documents, and Congressional reports.
Notes: Figures do not include prior year rescissions. NIFA funding figures include non-R&D components.

The U.S. Department of Agriculture (USDA) is facing another year of double digit percentage cuts to its research and development (R&D) portfolio due to both the moratorium on earmarks and the effort to reduce federal spending. In the FY 2011 continuing resolution (CR), the USDA suffered a $274 million (10.5% percent) cut to its R&D investment. In addition, the Agricultural Research Service (ARS) Building and Facilities account had $230 million of prior year appropriations rescinded. Of the $274 million in cuts, $247 million was former earmarks, $115 million in ARS and $132 million in the National Institute of Food and Agriculture (NIFA). In early Congressional action on the FY 2012 budget, many USDA R&D programs are facing larger cuts than last year. In the House Agriculture appropriations bill (H.R.2112), ARS received a $146 million (12.9 percent) cut from FY 2011 to $988 million, NIFA received a $203 million (16.7 percent) cut, and NIFA's competitive, extramural funding program, the Agriculture and Food Research Initiative, had its recent budget gains erased with a $37 million (13.9 percent) cut.

While other food, nutrition, agriculture, and natural resource related agencies fared better in the FY 2011 CR than USDA and are slated for increases in the President's FY 2012 budget request, they will likely face much smaller increases or slight decreases in Congressional action. Early House action supports this outlook with the Department of Energy's Office of Science facing a small decrease of 0.9 percent to $4.8 billion and proposed National Science Foundation funding of $6.9 billion, the same level as in FY 2011.

Food, Nutrition, Agriculture, and Natural Resource Sciences in the FY 2012 Budget

Excerpt from the "AAAS Report XXXVI: Research and Development FY 2012"
Visit http://www.aaas.org/spp/rd/rdreport2012/ to read the full Report.

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Highlights

Budgetary burdens will encourage USDA research agencies to reinforce ongoing and cultivate intra- and interagency partnerships, leveraging resources to ensure effective solutions to the 21st Century challenges on a local to global scale.

The looming budget deficit is reflected in the FY 2012 budget request of $2.2 billion for research and development in the United States Department of Agriculture (USDA), which eliminates $246 million in earmarks and is 17.7% below FY 2010. Probable elimination of research earmarks will impair university and Agricultural Research Service (ARS) research capabilities and increase pressure on competitive funds to address grand-societal and local challenges.

Introduction

Agricultural products and services contributed $121 billion to the United States (US) annual gross domestic product (GDP), supported 2.2 million jobs, and contributed $20 billion in net annual exports in 2006. Food manufacturing supplied $160 billion of the US GDP and 1.7 million jobs. For every dollar invested in agricultural, food, nutrition, and natural resource research and development (R&D) returns $20 or more to the US economy. Even so, support for US agricultural R&D has been flat-funded since 2001 while state funding has precipitously declined.

Public sector US agricultural and forestry R&D is supported by five principal funding mechanisms in USDA: **intramural programs** of the *ARS, Economic Research Service* (ERS), and *National Agricultural Statistics Service* (NASS); **competitive programs** (e.g., AFRI) administered by the *National Institute of Food and Agriculture* (NIFA); NIFA **formula funds** for forestry and the 150-year-old *State Agriculture Experiment Station* program; the **US Forest and Rangeland Research** (FS R&D); and designated research projects – special grants and earmarks – administered by USDA research agencies. Each portfolio item has a unique role; as a result, significant cuts to any mechanism will compromise essential transdisciplinary and transformative research.

New, competing 21st Century challenges in ***food security, food safety, nutrition and health, bioenergy,*** and ***climate change*** have refocused agricultural, food, nutrition, and natural resource sciences at a time of limited support for public sector R&D and training. These circumstances underscore the significance of ongoing, innovative partnerships between USDA's food and agriculture research agencies and universities and colleges; industry; professional societies; and other federal departments – ***Department of Health and Human Services*** (HHS), ***Department of Energy*** (DOE), ***Environmental Protection Agency*** (EPA), ***Department of Commerce, the National Science Foundation*** (NSF), and ***US Agency for International Development*** (USAID). These collaborations leverage USDA research portfolio dollars, providing indispensible expertise, intellectual capacity and infrastructure needed to overcome challenges that transcend borders.

Food Safety

Federal R&D funding for food safety exists within the USDA and HHS budgets, specifically the ***Food and Drug Administration*** (FDA). Related FDA research includes development of rapid detection and confirmatory methods, as well as investigations in biotechnology, virology, in vitro testing, and laboratory enhancement. A majority of FDA's food safety research is performed by the Center for Food Safety and Applied Nutrition. External research centers include the Joint Institute for Food Safety and Applied Nutrition, National Center for Food Safety and Technology, and Western Institute for Food Safety and Security. FDA's ***Transforming Food Safety and Nutrition Initiative*** requested an increase of $326 million over FY 2010 to implement the landmark Food Safety Modernization Act to establish a prevention-focused food safety system while leveraging the FDA's state and local food safety partners.

Within HHS, the National Institutes of Health (NIH) funded $290 million in FY 2010 in food safety research, primarily in the areas pertaining to microbiology of food and waterborne pathogens. ***National Institute of Allergy and Infectious Diseases*** (NIAID) food safety research totaled $208 million, funding over 450 projects in FY 2010, accounting for roughly 70% of NIH's $290 million budget for food safety research. Examples of NIAID research include: research on enteric diseases, biodefense food and water-borne diseases, system biology for enteropathogens, and development of experimental systems and animal models for studies of norovirus molecular biology.

In the FY 2012 budget, NIFA's AFRI includes a requested increase of $8 million for the ***Food Safety Challenge Area*** to support improved rapid detection methods, pre- and post-harvest epidemiological studies, and food harvesting and processing technologies, bringing the total AFRI request for food safety to $28.5 million. Increased funding will address research, education, and extension efforts in microbial ecology of food-borne pathogens and control of other food-borne pathogens of concern. In FY 2010, $20 million was allocated to the Food Safety Challenge Area which received applications amounting to $391 million that year.

ARS' Nutrition, Food Safety, and Quality National Programs current food safety research at USDA is designed to yield science-based knowledge on the safe production, storage, processing, and handling of products, and on the detection and control of toxin producing and/or pathogenic bacteria and fungi, parasites, chemical contaminants, and plant toxins. The proposed FY 2012 request is for $114 million, an increase of $6 million over the FY 2010 enacted.

ERS food safety research focuses on enhancing methods for understanding the benefits associated with reduced food safety risks; consumer willingness to pay for safer food; assessment of industry incentives to enhance food safety; and evaluation of regulatory options. ERS research extends to investigating the safety of food imports and the efficacy of international food safety policies and practices.

Food Security

Research on domestic food security – access to adequate food to lead an active, healthy life – is conducted by the ***USDA REE Mission Area,*** whereas global food security R&D is done by USDA REE and USAID.

While the USDA NIFA FY 2012 request proposes an overall 17.8% decrease in food security funding below FY 2010 levels, the budget requests a $62 million increase for the USDA NIFA's AFRI program, the agency's premier competitive research program, bringing funding to $325 million for FY 2012. The proposal includes an $11.8 million increase for the ***AFRI Global Food Security Challenge Area,*** resulting in a total request for this Area of $32 million for FY 2012. The budget requests an increase for the congressionally established ***AFRI Foundational Area*** programs, many of which apply to food security, bringing funding to $89.6 million for FY 2012. The NIFA budget also includes funding for the ***Sustainable Agriculture Research and Education*** (SARE) ***Federal-State Matching Grants Program*** increasing overall SARE funding to $30 million.

USDA ARS Animal Production and Protection and Crop Production and Protection National Programs support food security research in many areas with special emphasis on crop and livestock production. ARS's animal, insect, plant, and microbial germplasm collections within the National Plant Germplasm System (NPGS) provide an essential reservoir of genetic diversity and traits useful in overcoming abiotic and biotic stresses in production. For FY 2012, ARS requests an increase of $6 million to identify, acquire, and secure unprotected genetic resources. Increased support will allow the agency to tap these resources using a wealth of other "omics" technologies to deploy resistance genes to plant pests and pathogens and to enhance animal germplasm. The FY 2012 budget for ARS also includes a proposed increase of $15.6 million for crop and animal breeding and protection, including a $1.5 million proposal to strengthen grain disease research to protect the world grain supply and $4 million for livestock research to develop integrated, sustainable management systems that will improve food production and security. Total funding of $143 million is proposed for research related to food security at ARS in FY 2012, a decrease of 5.3% from the FY 2010.

The President requested $4 million for food security research at ERS, an increase of $2 million over FY 2010. This increase will enable ERS to determine how the USDA can enhance food security in US communities.

The NSF ***Biological Sciences*** (BIO) Directorate's ***Division of Integrative Organismal Systems*** (IOS) supports research and education aimed at understanding the diversity of plants, animals, and microorganisms as complex systems interacting with their environments. The President's FY 12 request includes a 7.1% increase for IOS above the $216 million included in the FY 2010 omnibus, which would allow 55% of the IOS portfolio to be available for new research grants. *The Plant Genome Research Program* (PGRP) is critical to genome-wide investigations that support biotech development. The PGRP's *Basic Research to Enable Agricultural Development* (BREAD) Program supports basic research on early-concept approaches and technologies for science-based solutions to problems of agriculture in developing countries. In FY 2012, NSF requests $6 million for the BREAD program.

The US EPA FY 2012 budget request for the ***Office of Research and Development*** (ORD) includes support for six base programs, including research on *Chemical Safety and Sustainability* (CSS). The request forCSS is $96 million, an $18 million increase over FY 2010. CSS research

supports the development and application of tools for the design of safer chemicals, including pesticide chemicals. Key areas of emphasis in FY 2012 include *Endocrine Disrupting Chemicals*.

The USAID **Feed the Future** (FtF) Initiative R&D request is $145 million for FY 2012. In FY 2010, FtF R&D included $35.5 million in funding for the *Consultative Group on International Agricultural Research* (CGIAR) program, an essential component of global long-term agricultural R&D, while the *Collaborative Research Support Programs* (CRSP) received $29.7 million.

Natural Resources

Research plays a key role in the development of information, technologies, and practices that can address natural resource protection issues and sustain the land's productivity.

Research on environmental stewardship performed within the ARS ***Natural Resources and Sustainable Agricultural Systems National Programs*** supports research in soil; water and air resources; and rangelands, pastures, and forages. The FY 2012 budget proposal includes a $1.8 million increase to enhance agricultural sustainability and resources management in the Mississippi River Basin and $2.7 million for improved management of microorganisms in agricultural systems. At the ***National Agricultural Library,*** $1.5 million is requested for FY 2012 to provide access to environmental data sets for the scientific community. Overall, the FY 2012 request for ARS' natural resources research totals $196 million, $12 million less than FY 2010 estimated.

Ongoing research at USDA ERS helps to improve information available about the relationship between Federal farm programs, farm production decisions, and the environment. ERS research also looks at the roles conservation programs can play in drought adaptation, adaptation to climate change, and water conservation. In FY 2012, the agency will research the factors influencing farmer adoption of best management practices to evaluate how adoption affects resource use, nutrient management, and the environment. A $2.4 million initiative in the FY 2012 budget request to create a ***Center of Excellence for Behavioral Economics*** supports this research. Funding for behavioral economics research is part of an overall budget request for FY 2012 of $86 million, a $3.5 million increase over the agency's FY 2010 appropriations.

NIFA administers the McIntire-Stennis Cooperative Forestry Research (M-S) Program which conducts research in forest and watershed management, reforestation, forest health protection, forest-based outdoor recreation, and utilization of wood products. The FY 2012 budget includes a 5 percent cut to the M-S program, requesting only $27.6 million. The Renewable Resources Extension Act (RREA) supports more than 4,200 programs that perform technical transfer, reaching 325,000 landowners, forest businesses, and policy makers, as well as the general public via intranet. RREA funds, authorized at $30 million and appropriated at $4 million, are available to LGUs and the Cooperative Extension Service. NIFA's FY 2012 budget has a 30.0 percent decrease in funding for the natural resource sciences under FY 2010 estimates.

The USDA Natural Resources and Environment (NRE) Mission Area's FS R&D conducts research directed toward sustaining healthy watersheds, forest products, wildlife protection, outdoor recreation opportunities, and other benefits. The President requests $296 million in FY 2012 for FS R&D, $16.3 million less than FY 2010 enacted, with $283 million designated for natural resource management.

The US EPA FY 2012 budget request for ORD includes support for six base research programs, among them are: Safe and Sustainable Water Resources (SSWR) and Sustainable and Healthy Communities (SHC). The request includes $118.8 million for SSWR research, an increase of $8 million over FY 2010 enacted to address critical science questions impacting the development and maintenance of safe, sustainable waters. Key areas of emphasis in FY 2012 will be water infrastructure, green infrastructure, and hydraulic fracturing. The budget request also includes $189.3 million for the SHC research program that focuses on environmental sustainability at the community level.

Nutrition and Obesity

NIH funds approximately 90% of public sector nutrition research, followed by USDA. In FY 2012, NIH estimates it will award $1.5 billion in grants for nutrition-related research, with $837 million funding obesity-related research. Although multiple NIH institutes and centers invest in nutrition R&D, the National Institute of Diabetes and Digestive and Kidney Diseases, the National Cancer Institute, and the National Heart, Lung and Blood Institute are the lead contributors, accounting for roughly 60 percent of total NIH nutrition-related spending in FY 2010.

In FY 2010, NIH funded nearly 4,500 nutrition research projects, and many examine the nutrition implications for chronic diseases. For example, the ongoing Vitamin D and Omega-3 Trial, receiving approximately $22 million over its first five years, determines whether vitamin D and fish oil supplements reduce the risk of cancer, heart disease, and stroke. In 2010, NIH launched two childhood obesity prevention initiatives: a seven-year, $54 million Childhood Obesity Prevention and Treatment Research program to evaluate long-term approaches for prevention, and a five-year, $30 million Healthy Communities Study to assess community-based approaches for reducing childhood obesity rates.

At USDA, ARS Nutrition, Food Safety, and Quality National Programs estimates it will fund $89 million in human nutrition research in FY 2012, including a proposed increase of $7.5 million for nutrition and health research to evaluate factors that influence adherence to dietary guidelines, determine accurate childhood nutrient requirements, demonstrate health benefits of certain foods, and improve the www.nutrition.gov website. The USDA ARS Human Nutrition program includes research on dietary guidelines, nutrition monitoring, obesity and related disease prevention, and life-stage nutrition and metabolism. In the FY 2012 budget, the President requested $87 million for the program's six Human Nutrition Research Centers. The Centers leverage resources through partnerships with federal agencies, universities, and commodity groups to address nutrition research.

Also at USDA, NIFA research has implications for improving diet, health, and food science. For FY 2011, anticipated funding for nutrition-related research within NIFA's AFRI was $37 million. NIFA investments include AFRI's Nutrition and Health Challenge Area and the related obesity prevention program funds research to identify behavioral factors leading to obesity, develop instruments for measuring the progress of prevention efforts, and evaluate prevention programs. In FY 2010, the program awarded $25 million for research targeting children ages 2-8 years, and budget increases of $8.5 million in FY 2011 and $8.2 million in FY 2012 aim to expand funding to research targeting children ages 9-14 and 15-19 years, respectively.

ERS allocated $15.8 million to nutrition research in FY 2010, and requested $16.5 million for FY 2012. In 2010, USDA ERS announced $2 million in grants for behavioral economics research on the outcomes of USDA Child Nutrition Programs.

FDA, the National Center for Health Statistics at the Center for Disease Control and Prevention (CDC), USAID, and the Department of Defense also fund a limited amount of nutrition research. NIH, USDA, CDC, and the Robert Wood Johnson Foundation work to improve the efficiency, effectiveness, and application of childhood obesity research, as members of the National Collaborative on Childhood Obesity Research.

Renewable Energy

The **Biofuels Interagency Working Group** is co-chaired by the Secretaries of DOE and USDA and the EPA Administrator. These agencies perform basic to applied research for the genetic development of biomass, sustainable production of feedstocks, logistics, and biomass conversion into advanced biofuels and value-added co-products.

The goal of the DOE ***Biomass and Biorefinery Systems R&D*** program is to ensure that cellulosic ethanol is cost-competitive by 2012. A total of $340.5 million has been requested for the Biomass Program, marking a significant increase over FY 2010. Within DOE SC's ***Office of Biological and Environmental Research*** (BER), the ***Genomic Science Program*** (GS) receives a significant increase, bringing the total request to $241.5 million for FY 2012. While the ***Bioenergy Research Centers*** received no increase (request is $75 million for FY 2012), the ***Joint Genome Institute*** (JGI) receives a small increase of $1.8 million in the budget request. The JGI is an essential infrastructural component which uses tools from contemporary systems biology to understand and predict the energetic relationships between microbes and plants. The increase would support synthetic molecular toolkits that predict, design, construct, and test new biological systems for clean energy solutions.

The USDA ARS ***Biofuels Research Centers*** coordinate federal research to accelerate the development and deployment of dedicated energy feedstocks for US regions. In the FY 2012 budget, an increase of $6 million is requested, bringing ARS bioenergy investments to $37 million.

The USDA NIFA FY 2012 budget request has an 8.7% increase for renewable energy research over FY 2010, bringing investments in energy programs to $112 million. DOE and USDA's NIFA jointly administer: ***Plant Feedstock Genomics for Bioenergy*** and the ***Biomass Research and Development Initiative (BRDI)*** to advance fundamental understanding of lignocellulosic biomass accumulation and other traits relevant to fuel production. In the budget, the BRDI request is $40 million, a 42.9% increase over FY 2010. NIFA also contains AFRI's ***Sustainable Bioenergy Challenge Area*** program which funds research on carbon sequestration, biomass feedstock protection, and utilization of co-products. Finally, the budget includes a request of $13 million for research on sustainable and efficient production, harvest, and conversion of liquid fuels, chemicals, and other high-value products within the USDA FS R&D ***Bioenergy and Biobased products*** investment.

Acknowledgements

Charles Valentine Riley Memorial Foundation

About the Partner Organizations

In 2008, the Charles Valentine Riley Memorial Foundation (RMF) selected the American Association for the Advancement of Science (AAAS) to receive an endowment to establish the annual Charles Valentine Riley Memorial Lecture *"to promote a broader and more complete understanding of agriculture as the most basic human endeavor and … to enhance agriculture through increased scientific knowledge."* A partnership between RMF, AAAS and the World Food Prize Foundation (WFPF) was then formed to implement the annual lecture. Collaboration between AAAS, RMF, and WFPF provides a unique opportunity to build upon Charles Valentine Riley's legacy as a "whole picture" person with a vision for enhancing agriculture through scientific knowledge. Professor Riley's involvement with AAAS, beginning as a member in 1868, being elected a Fellow in 1874, and serving as Vice President for the biology section in 1888, brings into the perspective his broad view of how science affects agriculture when placed in the broadest context.

AAAS
ADVANCING SCIENCE, SERVING SOCIETY

The American Association for the Advancement of Science is the world's largest general scientific society and publisher of the journals *Science* (www.sciencemag.org), *Science Signaling* (www.sciencesignaling.org), and *Science Translational Medicine* (www.sciencetranslationalmedicine.org). AAAS was founded in 1848, and serves 262 affiliated societies and academies of science, reaching 10 million individuals. The non-profit is open to all and fulfills its mission to "advance science and serve society" through initiatives in science policy, international programs, science education, and more. More information about AAAS and its diverse portfolio of activities can be found at www.aaas.org.

Charles Valentine Riley Memorial Foundation

The Charles Valentine Riley Memorial Foundation is committed to promoting a broader and more complete understanding of agriculture and to building upon Charles Valentine Riley's legacy as a "whole picture" person with a vision for enhancing agriculture through scientific knowledge. RMF, founded in 1985, recognizes that agriculture is the most basic human endeavor and that a vibrant and robust, food, agricultural, forestry, and environmental-resource system is essential for human progress and world peace. RMF conducts a wide range of program activities that include discussion groups, forums, round tables, workshops, briefing papers, and lectures on various parts of the food, agricultural, forestry, and environmental-resource system. The Foundation's goal is to have all world citizens involved in creating a sustainable food and agriculture enterprise within a responsible rural landscape. More information is available at http://www.rileymemorial.org.

World Food Prize Foundation

Founded by Nobel laureate and "Father of the Green Revolution" Dr. Norman E. Borlaug, the World Food Prize is a $250,000 award presented annually for breakthrough achievements in science, technology, and policy that have improved the quality, quantity, and availability of food in the world. Termed "the Nobel Prize for Food and Agriculture" by several heads of state, it is presented each October in conjunction with a week of events that include the international "Borlaug Dialogue" symposium and gather pre-eminent global leaders and experts representing over 65 countries. The 2011 World Food Prize events will take place October 12-14 in Des Moines, Iowa. Information about the World Food Prize events, highlights from past Borlaug Dialogue symposia, and nomination criteria are available at www.worldfoodprize.org.