



2016

Proceedings of the 2016 AAAS Charles Valentine Riley Memorial Lecture

The Role of U.S. Research Universities in Meeting the Global Food Security Challenge

Organized in collaboration with the Charles Valentine Riley Memorial Foundation and the World Food Prize Foundation

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FOREWORD

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



“There is no shortage of great ideas around the globe in agricultural science.”

— Chancellor Randy Woodson, 2016 AAAS Riley Lecture

The challenges of global population growth and the impact of climate change coupled with the consequences of continued underinvestment in agricultural research were the central themes of the 2016 AAAS Charles Valentine Riley Memorial Lecture.

Science and technology offer vital tools to address the growing challenges facing global food production in a rapidly changing climate. But, as cautioned by our panel of distinguished speakers, to meet these challenges, our nation's system of food and agricultural research must be considerably reinvigorated. And knowing that it takes years to realize the returns of research investments in these areas, increases in both public- and private-sector research and development funding are needed now.

Promoting agriculture and agricultural research as a basic human endeavor was at the core of Charles Valentine Riley's beliefs, and the foundation for the creation of this important lecture. We recognize and thank our colleagues at the Charles Valentine Riley Memorial Foundation and the World Food Prize Foundation for their substantial input. We also graciously thank our sponsors for their continued investment in this critical discussion.

On the pages that follow, you will find the text of the 2016 AAAS Charles Valentine Riley Memorial Lecture, a summary of the lecture and panel discussion, as well as information on federal funding for research in this area. The table and analysis included present updated figures from the *Guide to the President's Budget: Research & Development FY 2017*, produced earlier this year by AAAS.

The obstacles are great and the need is urgent, but we have confidence that with continued global focus, increased collaboration among public and private partners, and significant investment, we will be able to meet the challenge of feeding this and future generations.

Rush D. Holt
Chief Executive Officer, AAAS
Executive Publisher, *Science* family of journals



LECTURE AND PANEL DISCUSSION SUMMARY

Juan David Romero

Communications Officer, AAAS

Originally posted on www.aaas.org

In a keynote address delivered by Randy Woodson, chancellor of North Carolina State University, and during a follow-up panel discussion moderated by M. Peter McPherson, president of the Association of Public and Land-grant Universities, participants explored strategies to mitigate the impact of climate change and population growth on agriculture across the globe.

“I don’t have to tell you that agriculture in this country and around the globe is facing incredible pressures and growing challenges every year simply by a growing population,” said Woodson.

By 2050, the world’s population is estimated to reach as many as 10 billion people and increased demand for food will require 50 percent more food to be grown, produced, processed, and shipped, Woodson said. Atop that, climate change is expected to reduce crop yields by 25 percent. Some nations and regions that lack access to necessary technologies and scientific research will be particularly hard hit, he added.

Federal agencies such as the National Institutes of Health, the National Science Foundation, and the U.S. Department of Agriculture will have to devote more funding to agricultural research to help the industry meet the expected surge in demand, Woodson added.

Chavonda Jacobs-Young, administrator of the U.S. Department of Agriculture’s top research arm, said the agency has a wealth of information mapping agricultural trends, from crop growth levels to environmental risk that can help policymakers

formulate response plans. More data analysts and analytical tools are needed, however, to better leverage the information.

“We need young people who have energy, who understand biology and informatics, to come and help us figure out how to bring together systems of data that weren’t created to talk to one another,” Jacobs-Young said.

The United States is in a unique and enviable position, said Jacobs-Young, with a wealth of agricultural research from multiple government institutions and land-grant colleges and universities. With a unified effort, she said, experts should be well-equipped to protect agricultural resources.

“There is a need for the USDA research, the land grants, the non-land grants, and private research,” added Steve Verett, executive vice president of Plains Cotton Growers Inc. “We have to figure out how all of us can work together without worrying about who’s getting the credit for what, because I can tell you that the people on the ground don’t care.”

Carl Bednarski, president of the Michigan Farm Bureau, agreed that land-grant universities play a significant role in advancing agricultural practices through research, adding, though, that research findings from land-grant institutions could lead to more advances in agricultural practices with better collaboration between researchers and farmers.

For his part, Woodson expressed optimism about the potential of emerging technologies to help plant breeders fight plant diseases, fend off insects, and boost production levels. Among the technological advances available, he pointed to the arsenal of molecular biologists, including the CRISPR/Cas9 genome-editing tool, and miniaturized sensors that can be set on aerial and land-based platforms to track plant soil nutrients and moisture levels, and assess rates of yield production.

“Everything from integrated databases to real-time automated workflows and tools like DNA and spectral imaging of crops — the vast amount of data that we are able to get as we move plants through the pipeline is phenomenal,” Woodson said. “But to get this to speed up, we need to build ... networks that connect all of these sources of data with the plant breeder to move products to market more quickly.”

Verett said data collected by farm business networks, a climate tracking division of Monsanto Co., the biotechnology giant, and other online data sources are helping inform the industry to generate potential solutions facing growers, and all of it can be more easily shared. He too, though, said improvements about how big data is collected and used are needed.

“They give you all of this free information and you can see how much it rained on your farm, and with a bunch of maps out there you can record everything and that is great, but at the end of the day just having all that information does not do you any good. It’s

what you do with that information and how you use it effectively,” Verett said.

Collaboration is the key, according to Woodson, for creating an environment where scientists and engineers can cooperate to find ways to reverse problems such as crop yield loss in developing nations, increases in plant diseases, and more pests due to higher temperatures.

“There is no shortage of great ideas around the globe in agricultural science,” he said, stressing the need to take advantage of talent and offer more degrees in academic fields such as data science to train the next generation.

“We have a great challenge, and it’s a challenge to feed a growing population,” Woodson concluded, calling for sustainable solutions.



THE ROLE OF U.S. RESEARCH UNIVERSITIES IN MEETING THE GLOBAL FOOD SECURITY CHALLENGE

Randy Woodson

Chancellor, North Carolina State University

Good afternoon and thank you for the opportunity to join you today. It is a great honor and privilege to be asked to give the 2016 AAAS Riley Memorial Lecture. I am grateful to be able to share my thoughts with you.

I would also like to thank Rush Holt and AAAS for sponsoring the Riley Memorial Lecture. I am grateful to the Riley Foundation and all the sponsors of this important annual event. And I would also like to thank all of you for joining us today. This is where the solutions to agriculture and food system challenges begin — right here, with all of you, and I thank you for your participation.

I don't have to tell you that agriculture in this country — across the entire globe, really — is under some incredible pressures. It faces many challenges that are growing every year. The challenge of keeping pace with a growing population, the challenge of limited access to natural resources, and the challenge of providing adequate access to food, both calories and nutrition, around the world.

This afternoon I want to talk to you about technology in the context of addressing the grand challenges facing agriculture and food systems. Technologies that address crop improvement through both traditional breeding and biotechnology. Technologies like precision agriculture — geographical information systems, or maybe sensors, even robotics, as well as new crop protection technologies.

It's hard to read a newspaper these days without seeing a story about self-driving cars. Self-driving cars? Who ever imagined that 20 years ago.

Smartphones, 3-D printers, virtual reality ... the list goes on.

I think the technology that is pushing us headlong into the 21st century needs to — and will — step up and help us solve the challenges facing agriculture. It's going to have to. I don't know about you, but I like to eat on a regular basis — several times a day, in fact.

The Challenges

By 2050, it's estimated there will be 9 billion people to feed on this planet. To do that we will have to produce at least 50 percent more food than we currently do. Some estimates have the population at 9.7 billion. The World Bank predicts climate change could reduce crop yields by more than 25 percent. We are facing limited access to the national resources needed for the production of food.

In the United States, according to Farmland.org, more than 24 million acres of agricultural land — an area larger than the states of Indiana and Rhode Island combined — were developed between 1982 and 2010. This includes cropland, pastureland, rangeland, and land enrolled in the federal Conservation Reserve Program.

And there is the challenge of providing adequate access to food. In the United States, the USDA reported that 14.5 percent of American households were food-insecure at least some time during 2010. Of the 14.5 percent that were food-insecure, 5.4 percent were classified as having very low food security — defined by the USDA as “reports of multiple indications of disrupted eating patterns and reduced food intake.”

Food insecurity is a global issue. Consider these sobering statistics from the World Food Programme from March of this year. In South Sudan, 2.84 million people are facing crisis or emergency food security conditions. In Ethiopia, El Niño-induced drought has rendered 10.2 million people in need of food assistance. More than half of the population of Yemen is food-insecure. In Syria, an estimated 6.3 million people are food-insecure and another 2.4 million face a high risk of food insecurity. I could go on, but you get the idea.

We know we are experiencing changes in our climate. Growing food in a changing climate exacerbates the challenges of producing safe and nutritious food. Also, the delivery of nutrients to consumers is a challenge. We need to focus on assisting with global food security and maintaining abundant yields. It takes roughly 20 different nutrients for proper plant growth. Not only can this limit yields, it can affect the nutritional value of crops.

Right now, more than 2 billion people have iron deficiency anemia — that includes two-thirds of women and children in low-income nations. And it is the most common nutrient deficiency in the world, affecting almost 40 percent of the global population and causing over 100 million U.S. dollars per year in lost crop productivity. And if that weren't enough, we must find a way to manage new pests, pathogens, and invasive plants.

Those challenges can be met. It reminds me of an old quote I saw online recently: *“It's not about how bad you want it ... it is about how hard you are willing to work for it.”* Meeting those challenges is going to take

a lot of hard work. But we can, and we will. And those solutions will come through the use of technology.

Technology

There are many excellent examples of using technology for the improvement of agriculture, but we need more innovation.

One of our greatest opportunities for agriculture are data integration and communication of data. Management decisions that are site and stress-specific, things like water, nutrients, insects, and diseases, need to be made within minutes, not days or weeks as is the case now.

Imagine just-in-time delivery of yield-optimizing inputs whose quantities are dictated by predicted global weather patterns and economic conditions affecting input costs and predicted market price of commodities. In order to make wise and efficient management decisions, we'll need earlier and more accurate detection of stress — water, nutrients, insects, and diseases.

Data is the key and there will be vast amounts of it. We'll need to fuse and analyze these extremely large data sets with models that predict global issues affecting input price and market value. So how do we make that happen? Let me offer four advances that are needed.

We need miniaturized, rugged sensors adaptable for aerial or land-based platforms in agriculture. Advancements such as hyperspectral imaging — and the ability to process it — from aircrafts, satellites, and UAV allow for unprecedented

knowledge. That will assist in learning more about field-level phenotyping, yield potential and prediction, moisture stress, plant-soil nutrient status, plant-soil water, biomass-leaf area, pests and disease, and weed identification.

We will need the ability to capture and identify spectral signatures specific to key pathways affected by stress or plant deficiencies such that remediation of these yield-limiting factors can be applied immediately.

One approach we might be able to explore is the use of sentinel plants engineered with spectral reporters that monitor specific pathways in the plants associated with a specific stress and that transmit spectral signatures specific to that stress to remote sensors.

We will need the integration of plant spectral data with weather, crop, soil, and nutrient models to develop management models for high-yield sustainable agriculture.

And finally, we will need big data analysis software capable of providing management strategies within hours rather than days.

There are currently no data analysis models available to agriculture capable of rapid integration of the multiple crop input models and economic models for rapid management decisions in agriculture. It's important to remember, however, that, unfortunately, not everyone could benefit. Small agriculture operations provide up to 80 percent of the food supply in Asia and sub-Saharan Africa. Those technologies might not be practical or available. We need to consider scale and access to solve global food production problems.

Plant Breeding

Agriculture needs another disruptive technology. In the past we went from mules to tractors, we saw the advent of Haber-Bosch and fertilizer — reaction to fixed atmospheric nitrogen dioxide into fertilizer, hybrid seed corn, and dwarf wheat.

What is that next disruptive technology? Will it be gene editing? Gene editing is the most obvious place to go for technology advances.

At NC State, we have a rising young star by the name of Dr. Rodolphe Barrangou who is at the forefront of that research. His work with CRISPRs and gene editing has some incredible health and scientific implications — it's breakthrough stuff. He has distinguished himself with his outstanding research. And just this year he has been the recipient of two major awards — the Warren Alpert Prize from Harvard and the Canada Gairdner International Award, one of the world's most-esteemed medical research prizes.

CRISPR is one of the biggest scientific breakthroughs in quite some time. The power of this system is in its versatility. It allows one to make targeted deletions, insertions, and gene knockouts; turn gene expression on or off; tag nucleic acids for microscopic imaging; and study epigenetic effects.

Many desirable plant traits involve when and how much to turn genes on and off. CRISPR technology can do this in a very precise way, opening the door to improved yield and drought resistance without GMO technology. It's worth noting that some of this work may fall outside regulatory authority.

The U.S. Department of Agriculture recently ruled it will not regulate a mushroom genetically modified with the gene-editing tool CRISPR — Cas9 because it contains no introduced DNA.

Conventional Breeding

Of course, let's not forget about conventional plant breeding. Right now we are generally seeing increased yields of about 1 to 1.5% per year across most crops. But often the germplasm base used in crop production is very narrow. There are risks in adopting and deploying the same single genes — even if they are wonderfully improved genes — or the same germplasm stocks, no matter how good they are today. Currently deployed germplasm can be vulnerable to emerging diseases.

We need to make sure there are measures in place to diversify crops or groups of crops grown on farmers' fields. That will help ensure that past and current gains are not lost through disease, insect, or climate impacts.

Also needed, programs to identify and incorporate favorable alleles for prioritized traits from exotic sources for all major food crops. Traits can be mined and used from wild accessions through conventional breeding or assisted by genomic technologies. In cases where we cannot find the genes and traits in genetic seed banks, we will use gene-editing technology to tailor and create the needed trait.

Artificial Intelligence

We should consider the use of artificial intelligence and machine learning to provide faster and more agile, predictive breeding. Right now the current pipeline for releasing a new plant variety is five to seven years to get to a large-scale trial for grain. Then it's 10 to 12 years to release cultivar and another four to six for product tests. So commercialization can take 14 to 18 years even without it being a GMO.

We can and must do better than that. We need to get data out of databases and integrate it in real time into automated workflows and suites of application tools, things like DNA, images, proteins, traits, metabolites.

We need logical workflows to build neurological networks, and we need to improve plant breeding with virtual crosses based on models across all traits. If we do that, perhaps we can shorten the timelines from 10 to 12 years to six to seven years.

Developing World Interventions

Let me touch on streamlined food technology. This might not come to mind as a high-tech solution — technology is not in making the product — but we can show in a lab that a simple technology can have really big advances for food and human health.

At our NCSU Plants for Human Health Institute, Dr. Mary Ann Lila and her colleagues are finding new ways to bind health protective, immune-enhancing bioactive compounds from fruits and vegetables with shelf-stable food ingredients. In one study, they start with kale juice, which has very good anti-oxidant and anti-inflammatory compounds (high in polyphenols

and glucosinolates), and co-dry it with high-protein, hemp flour and soy protein isolate.

This promising technology could see application in MREs for the military, trail mix or crackers for hikers, but much more importantly, it could provide an avenue for solving real food crises with local foods in developing countries.

Right now, hidden malnutrition in Zambia causes a huge stunting problem. There is inadequate nutrition during the six-month dry season when dried corn grits — *nishima* — are the daily staple. But by combining seasonal fruits such as mango and guava — that would be otherwise wasted — with peanut we can get a stabilization of the fruits' active ingredients over the course of the dry season, without refrigeration.

Plant-Soil Interface

One thing to keep in mind, and one that might be obviously apparent, is the plant-soil interface. We can't forget that one.

Did you know that more water travels through the roots of plants than through rivers to the oceans? And there is still a tremendous amount of research required to fundamentally understand how water flows into roots. We lack significant understanding of how heat and water couple to fundamentally drive water movement between plants, soil, and the atmosphere.

In addition, advances in management and plant breeding at NCSU are improving water use and drought tolerance. Nearly all noncarbon nutrients are taken up through plant roots. There are approximately 20 nutrients required for plant growth. If macronutrients are sufficient, then micronutrients can limit plant growth. The plant and its symbionts can affect nutrient uptake, with the specific chemicals released by the plant or associated microbial community affecting nutrient dynamics.

NC State Research

With that in mind, is it possible to modify plants or their symbionts so that they more effectively extract water and nutrients from the rhizosphere? We have much to discover about how crop management and mycorrhizal fungi affect plant growth. We have a great deal to learn about the soil microbiome.

Can we treat the root zone as a system that can be optimized for plant growth? Owen Duckworth (Department of Soil Science) studies how plant, bacterial, and fungal exudates affect the solubilization and bioavailability of metal nutrients.

USDA-ARS scientists working at NC State are improving conservation agricultural systems to increase soil resilience by minimizing soil disturbance and extend the depth and diversity of roots on individual farms and fields.

Pest and Pathogen Control

Let's talk about pest and pathogen control for a moment, starting with emerging plant diseases.

Plant diseases and pests have been a scourge of agriculture ever since man moved from hunter-gatherers to growing crops in monoculture. The pace and unpredictability of these epidemics are accelerating due to global climate change.

We have all heard of the Zika virus and other human hemorrhagic fevers. Their appearance is due to the mosquito vectors range moving north from the tropics to the subtropics and temperate regions of the world. The same thing is happening with plant diseases, many of which are vectored by insects whose ranges are increasing due to climate change.

Many diseases that were more tropical curiosities are now becoming global threats to agriculture.

A big-systems science approach is needed to combat these emerging pathogens and challenges, starting with plant breeding for resistance. The difference now is plant breeding needs to be industrialized to accelerate the rate of discovery and deployment of new resistance genes. The key to success is rapid identification of emerging pathogens and pests followed by accurate, simple, and reliable field-level detection.

There are many new solid-state, microfluidic, remote-sensing, and other technologies being developed to diagnosis and detect pathogens on a continental scale. Combined with this are geospatial technology with data mining, crowd sourcing, and big data analytics to predict sensitive crop genotypes and the projected spread of the diseases and predicted yield losses.

This information helps global markets adapt to crop losses and provides farmers with information on the deployment of control strategies.

Weed Science

Herbicide-resistant weeds threaten sustainability of agronomic and horticultural crop production. Tremendous strides have been made over the past two decades to implement conservation-tillage agriculture. Effective management of weeds with herbicides has been critical in this adoption, but overuse has led to the evolution of herbicide-resistant biotypes.

Growers are moving away from conservation-tillage back to conventional-tillage systems, threatening gains made in conservation programs. In particular, sequestering soil organic carbon, which is critically important for biological attributes (e.g., reservoir of metabolic energy, source of macronutrients, enzymatic activities, and ecosystem resilience) as well as physical attributes of water infiltration, nutrient cycling, and protection of off-site water quality are vital for sustainable agricultural systems.

For crop production to be profitable, weeds must be controlled in the short term. NC State is providing solutions to herbicide resistance in fundamental and applied areas of research and the extension of that research to practitioners across all landscapes.

Adoption of technology in developing countries is needed in order to minimize yield loss and reduce the burden of hand removal of weeds. NC State's weed science program is involved in research and extension efforts in Africa to increase yield and efficiency of production through adoption of herbicides and other proven technologies.

Our program is evaluating all major technologies including genetically engineered crops and the

herbicides used within these crops. We are also investigating improved scouting and monitoring programs using UAVs, implementing state-of-the-art analyses of residues of pesticides and other compounds, and exploring the ecological and biological impacts of herbicide resistance on weed fitness and interference with the growth and production of desired plants and animals.

Genetic Pest Management

We know that we can address pest management through genetics. Take corn rootworm, for example. It's a major pest of maize, but the development of transgenic technologies will be the first step in bringing a wide range of sophisticated genetic tools to bear on that pest.

We can use transposon-based mutagenesis to understand basic rootworm biology and resistance development, and we are also investigating the feasibility of using CRISPR/Cas9-mediated gene drive for population suppression and local eradication of this pest.

Host-Induced Gene Silencing (HIGS) is another important example of a genetic technology being developed to improve crop production. Here, the host plant is used to deliver genetic material to invading pathogens that stops them in their tracks. HIGS is being developed to prevent rice blast, caused by the fungus *Magnaporthe oryzae*, which is one of the most destructive diseases of rice worldwide.

The basis for HIGS is gene silencing. Here, following the introduction of a HIGS construct into rice via plant transformation, small interfering RNA (siRNA) are expressed. Upon pathogen infection, these siRNA are delivered and targeted to genes in pathogens required for infection. This results in these targeted genes being silenced and infection stopped.

HIGS is effective against many plant pathogens, oomycetes, and nematodes. Moreover, it is expected to lead to duration resistance, since many pathogen genes can be targeted simultaneously.

Societal Challenges

Through all the research and science and new, big, bold ideas, there are also the societal challenges that need to be addressed. Everyone wants to eat, but agriculture isn't particularly sexy. When was the last time you saw an agriculture story on the cover of *Time*, or as a clue on *Jeopardy*? Agriculture isn't something I'll bet a lot of people think about on a regular basis. But we the scientists and researchers need to.

The United States is a nation of 318 million people. Forty-nine million of those people are food-insecure. That is a staggering 14.1 percent. There are a number of ways that we can supply the food deserts those people live in.

There are great opportunities to improve supply chain metrics, such as tracking agricultural products from the field to the consumer. We need to look at ways of improving the transportation, processing, and storage of food. That includes scale-appropriate technology.

Are the improvements to be made in the infrastructure of our food systems?

GMO Decisions

And then there are the discussions we need to have about genetic engineering. I mentioned earlier about how CRISPR-Cas9 falls outside regulatory authority. There is no doubt going to be great debate about that.

We know that affluent shoppers and other economically able people want organic, not transgenic foods.

The next consideration after the science of engineering is the communication of it. Consumers need to be educated about GMOs. They need the facts. They need the information to see beyond the Franken-food fear mentality. We know there are many people who will not eat transgenic food. Yet many of those same people are willing to be injected with transgenic products.

Interferon produced in chickens, humanized antibodies from chickens and cows, and antithrombin from goats. Yet when it comes to GMO

foods, it's a nonstarter. The grocery stores are filled with organic produce and other organic foods, but we know that organic production as we know it will not feed the world. A large and sustained education effort is needed when it comes to GMO foods.

Agriculture Funding

So where does this leave us? The bottom line is that we are not investing adequately in agricultural research. The 2010 GAP report (Global Harvest Initiative, 2010) estimates that the increase in global TFP — total factor productivity — needed to meet the food demands of the growing world population is 1.75 percent per year, up from the current rate of 1.4 percent. Between now and 2050, this requires growth 25 percent faster than is currently the case.

Since it takes years to realize the returns on research investments, increases in both public- and private-sector R&D funding are needed now.

The National Agricultural Research, Extension, Education, and Economics Advisory Board recommended at least a 25 percent increase in the annual growth rate of funding of agricultural productivity-enhancing research and extension, while also funding other topics currently included in the agricultural research budget.

The 2015 federal budget provided \$30 billion for the National Institutes of Health and \$7.3 billion for the National Science Foundation. Those investments are quite robust compared to the funding provided by the U.S. Department of Agriculture — only \$1.1 billion.

We know that the research and development needed to develop new technologies for farmers frequently has long gestation periods. The time lags associated with public agricultural research are long, and the benefits from any particular research effort do not last forever.

Studies consistently report high social rates of return from public agricultural research — between 20 and 60 percent. Reported benefits are worth 10 to 20 times the estimated costs, or more.

These are amazing times we live in. The creation and application of new knowledge is advancing exponentially. Consider that Leonardo da Vinci was sketching out plans for a helicopter in the 1480s, but it took another 450 years for one to actually fly — in 1936. The Wright brothers first flew in 1903, and in only 66 years, we landed on the moon.

Scientifically, we live in amazing times — gene editing, synthetic biology, big data analytics, digitization, and interconnection.

But at the same time, we have a confluence of technology and grand challenges — emerging diseases, pests, invasive plants, population growth, climate change, environmental degradation, misinformation, and urbanization.

How are we going to address those challenges? What is the best approach, and how can we then ultimately solve those challenges? It will come from great minds and the application of technology. We know it will take large, continuing, sustained investment in agriculture and plant sciences. We really have no choice. We have to do it. The citizens of the world depend on it. I am confident we will get it done.

I would like to thank you again for the opportunity to speak with you today. It has been an honor and a privilege.

Thank you.

To view Dr. Woodson's full presentation, go to www.aaas.org/riley-lecture.



PARTICIPANT BIOS

Randy Woodson

Dr. Woodson was appointed the 14th chancellor of North Carolina State University on April 1, 2010. He brought to NC State more than 25 years of experience as an internationally renowned plant scientist and academic leader. At NC State, Dr. Woodson has solidified the spirit of the land-grant university and its hallmarks of commitment and service by spearheading efforts to increase college access. Dr. Woodson arrived at NC State from Purdue University, where he served as executive vice president for academic affairs and provost. He also served as the Glenn W. Sample Dean of Agriculture, associate dean of agriculture, and director of the Office of Agricultural Research Programs at Purdue. Over his decades long career in higher education, Dr. Woodson has contributed a substantial body of knowledge to the field of plant science, which has been published in more than 100 journal articles and book chapters. His research has covered topics such as plant genetics, molecular biology, biotechnology, and sustainable bioproducts development, spanning the gap between the detailed science of plant physiology and the practical application of this knowledge in the field of horticulture. His research has been featured in stories published in *Business Week*, *The Futurist*, and *Discover*.

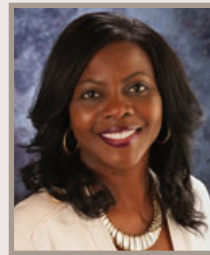
Carl Bednarski

Mr. Bednarski, a Tuscola County cash-crop farmer, was elected the 16th president of the Michigan Farm Bureau on December 4, 2014, at the MFB 95th annual meeting. In January of this year, Mr. Bednarski was elected to represent the 12-state Midwest region on the American Farm Bureau Federation board of directors. The Caro resident farms with his wife, Lisa, and their three sons, growing corn, dry beans, sugar beets, soybeans, and wheat. Prior to becoming president, Mr. Bednarski served as District 6 director on the MFB board of directors beginning in 2000. During this period, he was a long-standing member of the board's executive committee. His county Farm Bureau involvement includes six years as vice president and seven years on the executive committee. Mr. Bednarski has served in various leadership positions at the county, state, and national levels, including the membership, national affairs, promotion and education, and policy development programs, in addition to service on several commodity advisory committees. Beyond his Farm Bureau involvement, he is a past 4-H youth sugar beet program leader, a past vice chair of the Michigan Farm Produce Insurance Fund Board, and a founding member of the Michigan Sugar Cooperative, and he served on the Michigan Sugar board of directors for five years. He is a member of Sacred Heart Catholic Church and the Knights of Columbus.



PARTICIPANT BIOS

(continued)



Chavonda Jacobs-Young

Dr. Jacobs-Young has served as administrator of the U.S. Department of Agriculture's chief scientific in-house research agency since February 2013. Previously, Dr. Jacobs-Young had served as Agricultural Research Service associate administrator for national programs, where she led the Office of National Programs, which manages the research objectives of the agency, and the Office of International Research Programs, which is responsible for ARS' liaison with its international partners. Prior to moving into her roles at ARS, Dr. Jacobs-Young served as the director of the Office of the Chief Scientist at the USDA, where she was responsible for facilitating the coordination of scientific leadership across the department to ensure that research supported by and scientific advice provided to the department and external stakeholders were held to the highest standards of intellectual rigor and scientific integrity. She also served as the acting director for the USDA's National Institute of Food and Agriculture. Dr. Jacobs-Young has also served as a senior policy analyst for agriculture in the White House Office of Science and Technology Policy, where she supported the president's science adviser and others within the Executive Office of the President on a variety of agricultural scientific activities and worked across the federal government to improve interagency cooperation and collaboration on high-priority scientific issues.



M. Peter McPherson

Mr. McPherson is president of the Association of Public and Land-grant Universities. He is the co-chair of the board of directors for the Partnership to Cut Hunger and Poverty in Africa and is the chair of the Project Advisory Committee of HarvestPlus. Mr. McPherson is the former chair of the board of Dow Jones & Company. He was president of Michigan State University from 1993 through 2004. And from April to October 2003, he took leave from that position and served as the director of economic policy in Iraq (new currency, banks, etc.) under the Coalition Provisional Authority. In the years prior to being named president of Michigan State University, Mr. McPherson was a group executive vice president with Bank of America. While at Bank of America, he was responsible for BoA's banks in Latin America and Canada, and later its trust and private banking business. He was also chair of the U.S. banking community's advisory board on the negotiation of NAFTA. In the 1980s, Mr. McPherson was deputy secretary of the U.S. Treasury, the No. 2 position at the Treasury. In that

PARTICIPANT BIOS

(continued)



Steve Verett

position he was one of three U.S. negotiators in the final weeks of the U.S. Canadian Free Trade Agreement. Also in the 1980s, he was the administrator of the Agency for International Development (the U.S. foreign aid program). At USAID, he was responsible for the U.S. relief effort for the great famine in Africa in the mid-1980s, and expanded USAID work in agriculture. As USAID administrator, he was also chair of the board of the Overseas Private Investment Corporation. Mr. McPherson earned a B.A. in political science from Michigan State University, an MBA from Western Michigan University, and a J.D. from American University Law School. He has received several honorary doctorates.

Mr. Verett is the executive vice president of Plains Cotton Growers Inc., a regional cotton-producer organization covering 41 counties in the High Plains of Texas. He is a native of Crosby County, where he remains involved in a 4,000-acre farming partnership with his son, Kristofer, and brother, Eddie, including cotton, wheat, and grain sorghum production. He came to PCG in 1997 but certainly was no stranger to the organization, having served as board president in 1988 and 1989 and chairman in 1990 and 1991. Before joining PCG, he served as the executive director for the Texas Food & Fibers Commission. Mr. Verett is involved in numerous professional and community activities. He is treasurer of the Southwest Council of Agribusiness, board member of the Lubbock Reese Redevelopment Authority, and member of the Lubbock Chamber of Commerce's Government Affairs Committee, and he has served on the advisory board for the College of Agricultural Sciences and Natural Resources at Texas Tech University. He was selected as chairman of the Lubbock Chamber of Commerce in 2006, the first cotton producer ever to serve in that capacity. He is a graduate of Texas Tech and also of the Cotton Foundation's Cotton Leadership Program. Mr. Verett was most recently recognized by Farm Credit as a 100 Fresh Perspectives honoree in the Rural Policy Influence category.

FEDERAL FOOD, NUTRITION, AGRICULTURE, AND NATURAL RESOURCE SCIENCES FUNDING UPDATE

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

Prepared by Matt Hourihan, Director, R&D Budget and Policy Program, AAAS

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

(budget authority in millions of dollars)

	FY 2015 Actual	FY 2016 Estimate	Change Amount	FY 15-16 Percent	FY 2017 Budget*	FY 2017 House	Change Amount	FY 16-17 Percent	FY 2017 Senate	Change Amount	FY 16-17 Percent
Selected USDA Program R&D											
Agricultural Research Service (ARS)	1,208	1,386	178	14.7%	1,286	1,281	-105	-7.6%	1,272	-114	-8.2%
Natl Inst of Food & Agri (NIFA)*	809	838	29	3.6%	879	855	17	2.0%	869	31	3.7%
Agri & Food Research Init (AFRI)	325	350	25	7.7%	375	375	25	7.1%	375	25	7.1%
Forest Service**	302	315	13	4.3%	292	308	-7	-2.3%	287	-28	-8.7%
Forest and Rangeland Research	296	291	-5	-1.7%	292	302	11	3.8%	280	-11	-3.8%
U.S. Dept of Agriculture R&D	2,454	2,674	220	9.0%	2,598	2,581	-94	-3.5%	2,567	-108	-4.0%
Other Related Agency R&D Budgets											
National Institutes of Health***	28,750	30,618	1,868	6.5%	29,592	32,014	1,396	4.6%	32,780	2,161	7.1%
National Science Foundation	5,990	6,117	127	2.1%	6,160	5,929	-188	-3.1%	6,088	-28	-0.5%
Dept of Energy - Office of Science	5,099	5,305	207	4.1%	5,523	5,352	47	0.9%	5,352	47	0.9%

Source: AAAS estimates based on OMB R&D data, agency budget documents, and congressional reports. The spending bills providing appropriations for the above agencies have been approved by the appropriations committees in both chambers. Of these, only the Energy & Water bill has been approved on either chamber's floor (Senate, May 12).

*President's budget figures exclude new mandatory spending proposed for FY 2017.

**Includes \$3 million annually for Biomass R&D program.

***Excludes emergency Ebola-related funding in FY 2015 and proposed Zika-related funding in FY 2017.

ABOUT

CHARLES VALENTINE RILEY

Charles Valentine Riley (1843-1895)

“Professor Riley,” as he was generally known, was born in Chelsea, London, England, on September 19, 1843. He attended boarding school at 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 in 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 entomology 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



Charles Valentine Riley examining an insect.

succeeded in securing passage of a bill creating the United States Entomological Commission, the Grasshopper Commission administered under the director of the Geological and Geographical 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 Lügger, 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.” For a review of the cottony cushion scale project, see Doult, 1958.

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 the 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 and six children.

ACKNOWLEDGEMENTS

AAAS would like to thank the U.S. Department of Agriculture, National Agricultural Library for providing Professor Riley's biographical information and accompanying image. The Charles Valentine Riley Collection at NAL includes correspondence, unpublished lectures, photographs, news clippings, drawings, reprints, books, and artifacts covering the time period from 1868 to 1919.

ABOUT THE LECTURE

AND PARTNER ORGANIZATIONS

Launched in 2010, the AAAS Charles Valentine Riley Memorial Lecture aims to promote a broader and more complete understanding of agriculture as the most basic human endeavor and to enhance agriculture through increased scientific knowledge.



The American Association for the Advancement of Science

The American Association for the Advancement of Science is the world's largest general scientific society and publisher of the journal *Science* (www.sciencemag.org) as well as *Science Signaling*; *Science Translational Medicine*; a digital, open-access journal, *Science Advances*; and beginning in 2016, two new journals — *Science Robotics* and *Science Immunology*. AAAS was founded in 1848 and includes nearly 250 affiliated societies and academies of science, serving 10 million individuals. *Science* has the largest paid circulation of any peer-reviewed general science journal in the world. The nonprofit AAAS (www.aaas.org) is open to all and fulfills its mission to “advance science and serve society” through initiatives in science policy, international programs, science education, public engagement, and more. For the latest research news, log on to EurekAlert! (www.eurekalert.org), the premier science news website, a service of AAAS.



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 build 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, 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, roundtables, workshops, briefing papers, and lectures on various parts of the food, agricultural, forestry, and environmental resource system. RMF'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 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 includes the international “Borlaug Dialogue” symposium and gathers preeminent global leaders and experts representing over 65 countries. The 2016 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.