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Thank you for that gracious introduction. Ever since I learned about the invitation to give this lecture named in honor of my friend and colleague, John Kinsella, I have been thinking a lot about John and what he might like to hear. We shared some interests and experiences -- as you all know, John was a food chemist with interests in the biochemistry of dietary fatty acids, and my main field of expertise is nutrition with "continuing education" in food safety and, like John, my interests broadened and I learned lots more about agriculture when I became a Dean of Agriculture at a Land Grant University. We share an Irish heritage and we both received graduate degrees from Land Grant Universities.

I first met John in 1990 when I joined the Food and Nutrition Board of the National Academies of Science as its Executive Director and John was a member of the Board. He played a very active role in the work of the Committee on

Military Nutrition Research during his tenure on the Board. That might sound like a rather cut and dried assignment, but during his time with the Committee they took on some very interesting questions. Like: How much fluid replacement should troops get when working in very hot and dry environments? Their advice proved very important and changed the water doctrine that the US military implemented during the first Gulf War. That action dramatically reduced the number of cases of heat stroke in American troops. Or another interesting question: How much can we starve Army Rangers during training before they succumb to infectious disease? The Committee's advice led to a restructuring of the Ranger food protocols during training.

John approached all his work with the National Academies with great energy and good humor and made major contributions not only to the Food and Nutrition Board, but also to the Panel on Animal Health and Veterinary Medicine and the Committee on Technological Options to Improve Nutritional Attributes of Animal Products.

But it's been more than 20 years since John's premature death, and I thought that my lecture could be a conversation bringing an old friend up to date on the current perspectives on food and agriculture research. He would have foreseen some of the trends that have created the reality we're dealing with now, but there have also been some surprises that I would want to fill him in on.

The globalized food system is one of those recognizable trends. And the global food system that brings so many benefits also poses many challenges. The challenges include assuring food security, both domestically and world-wide, in the face of emerging diseases of crops and livestock, finite arable land, constraints on water, more severe weather, increased drought and fire risk, the global financial crisis from which we're slowly recovering, and a projection of global population growing to 9 billion by mid-century, which would require us to double our agricultural production. There's also the budding bioeconomy to which we're looking to agriculture as the alternative to petroleum and the source of chemical feedstocks for fuel, pharmaceuticals and other industrial products.

Our ability to meet and overcome these 21st century challenges depends upon a strong foundation of food and agricultural research. Our success in achieving food security and fulfilling all the requirements being put on agriculture to provide for the bioeconomy, provide ecosystem services and more – will depend on the foresight and success of our scientific endeavors.

In the work I do at USDA, we are focused on addressing five grand challenges: assuring food security both domestic and international, providing safe food, promoting lifelong health through improved human nutrition, building the bioeconomy, and (in order to accomplish all of this) developing long-term sustainable agricultural systems resilient to climate change. These are the priorities for research performed in intramural labs and supported at universities and each is complex and requires multi-faceted approaches to research. They are

also challenges that we are partnering with research organizations in other countries to address – and I'll speak to that in a moment.

Three of these grand challenges – food security, food safety, and human nutrition– are my focus today, and I would argue we need to address the three together in the context of climate change to achieve a food supply that is sufficient for our growing global population, safe and health-promoting, resilient to climate change, and sustainable into future generations. When I served as Under Secretary for Food Safety during the Clinton Administration, I used to say that no food is nutritious that is not safe. They go together.

So when I think about the food security challenge, I think we need to consider all aspects of producing a health-promoting diet that will be long-term sustainable: enough food; of the right mixture of fruits, vegetables, grains and animal products; and food that is free of disease-causing pathogens and toxins. The adaptation of agricultural systems to climate is increasingly the organizing principle for agricultural research and sustainable intensification of agricultural production is increasingly recognized as the key to food security.

I hope as we move toward that goal of climate-adapted-sustainable intensification of production, that we can begin to organize our thinking to also include the science we need to a healthful as well as sustainable diet. Calories will be important for 9 billion people, but not sufficient. Calories alone will not support our burgeoning population. So I'm very pleased that work is under way in the US and other countries to expand the models currently used to project the

effects of changing climate on agricultural production. Current models are based primarily on the major grain crops – rice, wheat, corn – the sources of calories from the starchy crops that are staples for people around the world. The work under way will expand the models to encompass fruits, vegetables and other sources of important nutrients to maintain good health.

Several years ago the Economic Research Service (ERS) did an analysis of what changes would need to occur in U.S. agriculture if Americans were to emulate the diet USDA recommends in Dietary Guidelines for Americans. The numbers are a bit out of date, but they paint a picture of the extent of change that would need to be made in agricultural production in order to provide the foods that we recommend for health promotion and disease prevention. Dairy production would have to rise, and production of legumes would rise dramatically while starchy vegetable production would fall, fruit acreage would have to double, but wheat production would fall off. Of course, we know that the U.S. population has not adopted all the recommendations, but the directions and magnitude of change in production are instructive as to how a healthful diet might influence future American agricultural production. I've challenged the Economic Research Service with a new question: Is a health-promoting diet going to be long-term sustainable?

At the moment, I don't believe we have a simple answer to the question of whether there is a healthy diet that is environmentally sustainable. We know we need protein in the diet, but the amount consumed in the US is far more than

required for good health. Some suggested diets would seem to limit the range and quantity of specific foods to unrealistic levels given human practices and tastes today. While vegetarian and even vegan diets are discussed often in the media, they are not emerging as diets selected/preferred by the majority of the American population by any means. And as countries move up the development scale, their populations are demanding more meat products. We have a lot to learn about the social, behavioral and economic factors influencing dietary patterns and food choices for populations and successfully combining that knowledge with their impacts on climate change.

Another challenge emerging for diet and climate change is the impact of rising temperature on the plants and animals – and insects, toxin-producing fungi diseases and other pests – as they respond to changes in their natural environment. What impacts will these factors have on our ability to produce healthful, sustainable diets?

New evidence is emerging about the impact of increasing temperatures on plants. In some cases, the growing season appears to be favorably extended and farmers are learning to adapt their planting times and select new varieties techniques to these factors. A recently published paper in *Nature* showed that rangeland plants exposed to increased temperatures and carbon dioxide levels could adapt with earlier spring growth and delayed fall senescence. So we are learning, but we need to learn more about many crops. An increase in local warming above certain levels results in crop yield losses or in actual micronutrient declines. Some

examples would be a 10% loss of anti-oxidant color compounds in grapes when there is a 2° C increase in temperature above 25° C. Lycopene and ascorbic acid in tomatoes both decline when the tomatoes are grown in heat above normal growing conditions (ascorbic acid declines by 3% when temperature is 25° C or above, and lycopene drops 7 fold when temperature goes above 23° C = 89° F.)

In addition we really need to be looking at post-harvest quality to examine the effect of these environmental changes on crop. This is especially true as we move to develop plants that are resistant to drought or to grow in higher temperatures.

But there is an ominous trend that is challenging our ability to provide the research base to address the grand challenges I've been discussing – and that is the decline in funding for agricultural research in the United States. Just last week the American Academy of Arts and Sciences released a new study called "Restoring the Foundation: The Vital Role of Research in Preserving the American Dream." The first sentence of the report states that "The American research enterprise is at a critical inflection point." They go on to make the case that the United States has slipped to tenth place among OECD nations in over-all research and development investment as a percentage of GDP and that has big implications for our future. The report makes the case that the public investment in fundamental research is the "lifeblood" of the economy and is essential for the economic and personal well-being of citizens. While this most recent report focuses on all public sector support for fundamental science, we can draw similar arguments for agricultural research.

The new report cites the iPhone as an example of how the public investment paid off. The iPhone depends on 7 or 8 fundamental scientific and technological breakthroughs – like GPS, multi-touch screens, LCD displays, lithium batteries, and others. But Apple made none of the discoveries – rather they came from research that the federal government supported at universities and in government labs.

Similarly, we can point to successes in agricultural production. Today in the US, about 9 million cows produce more than 21,000 pounds of milk per cow compared with less than 9,500 pounds that 12.5 million cows produced in 1970. That gain of more than 60% is attributable to publicly-funded genetics and nutrition research, and providing information to the dairy industry for herd improvement.

Historically, agriculture is more dependent on research for increases in productivity than other sectors of the economy. Yet, support for agricultural research has stagnated for more than two decades and dropped steeply during the economic downturn in 2011-2013. In December of 2012, the President's Council of Advisors on Science and Technology concluded that to meet the challenges facing agriculture, a renewed commitment to research, innovation and technology development in agriculture was needed and recommended that the public investment in agricultural research be expanded.

And last week, a report from the National Academy of Sciences concluded that "The global prominence of the United States as a producer and exporter of food and other agricultural commodities and its competitiveness in increasingly integrated international markets are inextricably tied to research-induced improvements in agricultural productivity. Even though rates of return on productivity-enhancing research are demonstrably high, the growth in public and private spending on agriculture and food R&D in the United States has been slowing, and the share of public funds focused on farm productivity-enhancing research has declined. Those surprising trends have led to a slow-down in US farm productivity growth at a time when the market has begun to signal the end of a sustained period of more than 50 years of global agricultural abundance."

Climate-adapted, sustainable-intensification is not the job of the United States alone. It's a global effort. The way we do food and agricultural science has changed enormously in the last 20 years – its international nature, the growth of cross- sectorial public-private partnerships, and increasing openness. Genetics and climate change researchers have led the way, embracing open access to data as a foundational principal for international research projects. The crop and food animal genomics programs have put open science into practice.

In this imagined conversation with John, I would want him to know that in so much of the work he did as a scientist, as Dean at UC Davis and as a volunteer on many Academy committees, he set into motion ideas that have shaped these trends in food and agriculture. Through his leadership at UC Davis, the faculty put

in place an academic plan that incorporated the agricultural and environmental sciences in ways that positioned the university to lead today's climate smart agricultural research. His research in lipid biochemistry laid the basis for dietary recommendations related to monounsaturated fats as beneficial food ingredients. And his championing public-private partnerships strengthened the California Dairy Foods Research Center and established new ways of working with the dairy industry. John Kinsella epitomized what we hope when we welcome students from other countries to study in the US. He flourished as a graduate student at Penn State University, and went on to a brilliant career at Cornell and then as Dean at UC Davis. Along the way, he made innumerable contributions both professional and private – as a mentor, colleague and friend – and left a large legacy.

It has been a great honor to give the first John Kinsella Memorial Lecture. Thank you.