Supporters of Agricultural Research Foundation www.supportagresearch.org
4601 N. Fairfax Drive • Suite 1120 • Arlington, VA 22203 P: 571-257-762

<u>Solicitation of Input from Stakeholders on Agricultural Innovations</u>
USDA-2020-0003

The Supporters of Agricultural Research (SoAR) Foundation is pleased to provide comments to the U.S. Department of Agriculture's (USDA) call for input from stakeholders on agricultural innovations. SoAR's Scientific Advisory Committee discussed the request and, through consensus, is providing specific responses to the questions posed in the *Federal Register Notice*. The following SoAR Board and Advisory Committee members participated and agreed to the input provided:

- Dr. Vicki Chandler (committee chair)—Member of the National Academies of Sciences; Provost of Minerva Schools at KGI; and a member of the National Science Board.
- Dr. Robert Cousins—Eminent Scholar and Boston Family Professor of Nutrition, University of Florida; Director, Center for Nutritional Sciences at the University of Florida; President Emeritus, Federation of American Societies for Experimental Biology; and a member of the National Academy of Sciences, Engineering, and Medicine.
- Dr. Elliot Meyerowitz—George W. Beadle Professor of Biology; Investigator, Howard Hughes Medical Institute, California Institute of Technology; and a member of the National Academy of Sciences, Engineering, and Medicine.
- Dr. Charles Rice—University Distinguished Professor of Soil Microbiology, Kansas State University; member of the United Nations' Intergovernmental Panel on Climate Change; Chair, Board on Agriculture and Natural Resources of the National Academies of Sciences, Engineering, and Medicine.
- Dr. Robert Easter—President Emeritus, University of Illinois; Professor and Dean Emeritus of the College of Agriculture, Consumer and Environmental Sciences, University of Illinois; Former Chair, U.S. Agency for International Development's Board on Food and Agricultural Development; Fellow, American Society of Animal Sciences.

The mission of SoAR's Scientific Advisory Committee is to strengthen agricultural research and raise its profile within the broader science community with a special focus on the Agriculture and Food Research Initiative (AFRI) within USDA. AFRI is the flagship agricultural competitive grant program within USDA's National Institute of Food and Agriculture (NIFA).

SoAR leads a non-partisan coalition working to educate stakeholders about the importance of agricultural research and focus more of the United States' best minds on feeding America and the world. For the U.S. to remain a global leader, public research funding that accelerates the productivity, profitability, and sustainability of American agriculture is needed. SoAR and its partners are working together to increase federal investments in agricultural research so the U.S. can continue to be a leader in agricultural innovation and production and that U.S. farmers and ranchers can continue to produce safe, nutritious food for the world's growing population. SoAR is committed to the full authorized funding level of AFRI at $700 million.

The COVID-19 pandemic has changed the landscape of everyday life in the U.S. for the foreseeable future. Farmers and ranchers have suffered devastating losses as a result of breaks in the food supply chain, resulting in plowing under of unharvested crops, as well as disposal of milk and eggs. Recovery from these losses could take years and some will face the need to change their business model in order to remain viable.

As stated in the July 2018 released National Academies of Sciences, Engineering, and Medicine (NASEM) report *Science Breakthroughs to Advance Food and Agricultural Research by* 2030,[1] business as usual won't solve the already overwhelming stresses on U.S. agriculture. The COVID-19 pandemic has exacerbated these stresses, and economic recovery is unlikely to be linear, especially if there are subsequent waves of infection. What we learn from this pandemic could be used to ensure that farming is more resilient to future challenges. This could involve diversification to include cultivation of new more resilient, high value crops and livestock varieties and improved crop and livestock management practices.

Additionally, the NASEM report emphasized that transdisciplinary research and systems approach to the agriculture and food system is needed by making it Breakthrough 1: "A systems approach to understand the nature of interactions among the different elements of the food and agricultural system can be leveraged to increase overall system efficiency, resilience, and sustainability."[Ibid] This concept has gained the attention of the private sector, with companies investing in systems-based farm management. *Science Breakthroughs 2030* also highlighted the importance of protecting the global food supply chain.[Ibid] COVID-19 has illustrated that a breakdown of supply chains exists in the agriculture and food sector, especially within the livestock industry.

By prioritizing transdisciplinary science and systems approaches, agriculture's most pressing challenges, like the current COVID-19 pandemic, can be solved. One additional aspect of these approaches, according to the report, is that leadership who understands the broad picture is crucial to making these approaches successful.

USDA has a unique opportunity to drive research to develop new crops and livestock varieties, as well as new crop and livestock management practices. Also, USDA can promote transdisciplinary research and systems approaches, more nimble and flexible approaches to benefit farmers, from research discovery to modeling, and provide leadership with these approaches in the agriculture and food sciences.

Answers to specific questions

1. *What agricultural commodity, group of commodities, or customer base does your response pertain to or would benefit?*

   SoAR's responses primarily benefit farmers and ranchers whose crops and livestock derive or benefit from researchers' efforts focused on crops, animals, and management practices at U.S. higher education institutions, including Land Grant Universities.

[1] https://www.nationalacademies.org/our-work/science-breakthroughs-2030-a-strategy-for-food-and-agricultural-research

2. *What are the biggest challenges and opportunities to increase productivity and/or decrease environmental footprint that should be addressed in the next 10- to 30-year timeframe?*

- ***Gathering, storing, managing, and effectively using enormous amounts of data***
  Agricultural research and modern agricultural practices are increasingly data driven and this will increase rapidly in the coming decades as new technologies are developed. The current laboratory and field data collection efforts are mostly dispersed and largely non-standardized, which hampers the development of integrated models for use in research and farm management.

  USDA's Agricultural Research Service (ARS) provides access to high quality research data sets, largely organized by organism (e.g. MaizeGDB)[2] as well as curated datasets for specific animal disease and nutritional issues (e.g. DGIL Porcine Translational Research Database).[3] The Functional Annotation of Animal Genomes Project (FAANG)[4] funded by NIFA and the National Science Foundation (NSF) supports the identification of all functional elements in animal genomes, important for identification of genomic selection and precision engineering targets. Its contributors are international and it promotes adherence to recognized data standards.

  For the most part, these repositories are not linked to allow systems-level analyses. Regarding crops, there are some fledgling research efforts such as *Crops in Silico* that aim to allow different data streams to be pulled together to facilitate metabolic modeling. Next generation field-based sensors for research and crop management will require a rethinking of how this is done. Regarding livestock, there are currently few efforts that integrate data to facilitate modeling although CyVerse[5] does allow import of data for analysis using its generic platforms. Other than cattle and poultry, genomic analyses do not account for the diverse product uses or different management systems.[6] Lessons can likely be learned from vendors like Amazon in AI and machine learning but there are also specialized needs for agriculture that will have to be addressed.
  USDA could play a leadership role in this area, linking public sector research efforts with private sector and end-user needs. This is something that would need to engage ARS in thinking about the future of its data repositories as well as other NSF-funded cyber infrastructure and tools such as CyVerse.

[2] https://www.maizegdb.org
[3] https://www.ars.usda.gov/northeast-area/beltsville-md-bhnrc/beltsville-human-nutrition-research-center/diet-genomics-and-immunology-laboratory/docs/dgil-porcine-translational-research-database/
[4] https://www.animalgenome.org/community/FAANG/
[5] https://cyverse.org
[6] https://www.frontiersin.org/articles/10.3389/fgene.2019.00327/full

- ***Increasing nutrient use efficiency in crop and animal production systems***
  More sustainable fertilization methods are needed if agriculture is to address climate change and environmental degradation. Not all fertilizers are inexhaustible and fertilizers are often over applied to achieve maximum yield even though the plants are not using all inputs. Changing these practices without significant yield losses will require an integrated systems approach to solutions from genetic improvement to crops as well as data-driven field management through advanced sensor deployment and modeling. Within a thirty-year timeframe, agroecosystem level management of plant nutrients could be possible integrating at scales from organism to environment over time. Specific steps to achieve this goal include:
  - Engineering of basic biological nitrogen fixation into any crop stacked with improved photosynthetic efficiency, and nutrient use efficiency for nitrogen and phosphorus in field-based settings.
  - Manipulation of the rhizosphere for enhanced plant health research on the root microbe interactions. Outcomes would improve phosphorus uptake, nitrogen fixation around the root, enhanced water use, and biocontrol of pests and diseases.
  - Modification of plant architecture below ground that focuses on nutrient and water uptake and that can be used for a wide range of plants and environments. Predictive modeling could allow the development of new plant varieties that anticipate future stresses resulting from the impacts of accelerated climate change (e.g. drought, flooding, temperature). Soil microbiome, specifically rhizosphere, research to enhance nitrogen fixation and nutrient acquisition is needed.
  - With sensors already a $1 billion market in agriculture, future efforts need to focus on improvements to existing sensors, as well as new sensors for nutrient fluxes and below-ground processes in crop plants. A new generation of sensors will also need to have the capacity to handle, network, and transmit huge amounts of data.
  - Exploration *via* modeling of moving away from monocultures of a few major crops to more diverse and resilient cropping systems. Perennial polycultures could be developed within thirty years capable of matching current nutrient outputs on the same acreage. This systems crop diversification approach could include cover crops, where research is needed for rapid growth, root characteristic, and summer cover crops for drought tolerance and nitrogen fixation.

- ***Soils research***
  Research is needed into the “dark matter” of soils – the bacteria and fungi that interact intimately with plants – that play a central role in plant nutrient uptake and about which we know very little. Soil microbes play a critical role in the functioning of soils. Support is needed for discovery research and its application for crop and soil health and ecosystem services.

- The plant-soil-microbe interaction in the rhizosphere provide vast opportunities for enhance crop health as noted above. Development of a new generation of engineered soil microbes is needed with improved water and nutrient management and disease resistance through enhancement of existing soil microbes and genetically-enhanced microbiomes. There is already an exciting burgeoning of start-up companies in this area and USDA has a unique opportunity to accelerate discoveries that will lead to new products.
- Enhancement of the soil microbiome in the role of soil carbon sequestration through advanced soil and crop management.
- Manipulating the soil microbiome for reduced nitrous oxide emissions to increase nitrogen use efficiency.
- Further research on soil health, both the fundamental aspects of the interrelations between the biological chemical and physical aspects of the soil and how the soil microbiome could be enhanced.

- ***Mobilizing genetic diversity for crop improvement***
  What is the future demand for food going to mean for arable land usage? What is it going to mean for nutritional content needs? How will the impacts of climate change factor into these strategies? Some potential approaches are:
  - Rapid surveying of legume diversity for new crops as feedstock for new plant-based foods and that offer enhanced nutrition. While the major grain crops are close to maximum yield potential thanks to decades of investment in genetic improvement, many legumes are not.
  - Rapid domestication of wild plants into new crops (e.g. pennycress for oils, broomcorn millet for intercropping, animal feed and fermentation feedstock, ground cherry as a nutrient-rich food) to meet specific needs, such as nutritional content, drought, and heat tolerance.
  - Identification of new candidate crop plants that have high potential market value, are well adapted to the changing climate, and have germplasm resources that can be rapidly engineered and distributed. USDA ARS would be a natural partner with DivSeek[7] (an international non-profit) for seed repositories, and the Consultative Group on International Agricultural Research (CGIAR) seed repositories could be partners in these types of project.
  - Use of model-based metabolic engineering of resource allocation across a wide range of plants to increase yield while increasing nutrient density.
  - Prevention of heavy metal accumulation in key crops through genetic improvements as more marginal arable land is used.

- ***Animal genetics and best management practices to promote sustainable agriculture***
  A sustainable agriculture system to meet the growing population's food demand will require an integrated, multi-pronged approach to animal genetics that addresses the

[7] https://divseekintl.org

whole life cycle and is integrated with improved husbandry practices. Goal 2 of the *USDA Blueprint for Animal Genome Research: 2018-2028*[8] recognizes the need to balance the use of current practices with improved sustainability of animal agriculture. Genomic tools and predictive modeling have yielded significant advances for cattle, but complex traits remain challenging and tools are only available for a limited number of species. Through one of AFRI's cross-cutting programs, Agricultural Innovation Through Gene Editing, USDA is able to help address this concern. Gene editing has the potential to accelerate animal, microbe, and plant breeding through generating beneficial traits or eliminating unwanted traits. This program funds projects that broaden the use of gene editing technology.

Breakthrough 4 of *Science Breakthroughs 2030* focused on the importance of gene-editing and recommended that initiatives be established to "exploit the use of genomics and precision breeding to genetically improve traits of agriculturally important organisms.[9] The impact of genomics is far reaching and has the potential to positively impact all aspects of the agriculture and food systems, including animal welfare.

There are several key priority challenges:

- The use of antimicrobials to boost yield is increasingly viewed as having negative impacts on the environment and human health. Existing genetic diversity could be used in combination with genomic selection and genetic engineering tools to accelerate the transition to more sustainable practices (examples: improved intestinal health and increased digestibility of feedstuffs not consumed by humans) for a wide range of animals.
- Moving to a systems approach for sustainability, and integration of data platforms for predictive modeling offers the possibility of breeding plant-based animal feedstock with co-selection of animal genotypes and custom microbiomes that together lead to lower methane emissions and improved nutrient sequestration. Through another AFRI cross-cutting program, Agricultural Microbiomes, USDA is supporting much-needed microbiome research that will improve agricultural productivity and sustainability, and the safety of the food supply.
- Many genes and networks associated with useful traits are derived from laboratory model systems. With advances in gene editing and the development of organism-agnostic tools, it should be possible to carry out these types of experiments in the relevant systems.

[8] https://www.ars.usda.gov/ARSUserFiles/02080000/Animal%20Genome%20to%20Phenome%20Executive%20Summary.pdf
[9] https://www.nationalacademies.org/our-work/science-breakthroughs-2030-a-strategy-for-food-and-agricultural-research

- Sensors are increasingly important in monitoring animal health and managing animal production, and have a key role in research.[10] Defining the relationships between genes or multiple genes and their corresponding phenotypes need to be a high priority if the full potential of new precision genetics and engineering tools is to be realized. There is also a critical need for development of rapid assays to accelerate phenotyping and precision genetics, and handling of massive data sets.

- ***Optimizing water and energy use in plant and animal agriculture***
  Agriculture (including irrigation, livestock production and processing, and aquaculture) is estimated to consume 69% of fresh water extracted from ecosystems and in the developed world, agricultural productivity has reached the maximum possible with the available rainfall or irrigation.[11] This includes animal product processing, with the amount of water consumed varying, depending on the livestock species and type of processing systems. A breakthrough in water use efficiency (WUE) is needed to sustain crop production and drive the next generation of agricultural improvements. Water use is closely linked to other plant functions including photosynthesis, metabolism, and a systems approach guided by models will be required to advance genetic improvements.

  Science Breakthroughs 2030 highlights the importance of Controlled Environments and Alternative Water Sources to help with optimizing water and energy use in plant and animal agriculture, including aquaculture and vertical farming. The report also emphasizes the importance of a systems approach to water management in order to provide a long-term solution.

  Examples of specific goals are:
  - Rapid development of crops with stacked traits such as WUE, Nitrogen Use Efficiency (NUE), drought tolerance, and improved photosynthetic efficiency in any crop through modeling, as well as testing of these across a wide range of environments. *Crops in Silico* is an early example of this type of platform.
  - Engineering of a wide range of crops for modification of photorespiration *versus* photosynthetic efficiency.
  - Building on ongoing public and private sector development of data-driven field management strategies from sensor data to predictive models to accelerate breeding and deployment of new crops.

- **Animal Production and Management**
  Chapter 3 of *Science Breakthroughs 2030* is dedicated to animal production. Even with decades of research and development to significantly improve the efficiency of

[10] Cole JB, Eaglen SAE, Maltecca C, Mulder HA and Pryce, JE (2020) The future of phenomics in dairy cattle breeding. Animal Frontiers 10:2, 37-44. https://doi.org/10.1093/af/vfaa007
[11] https://www.unwater.org/water-facts/water-food-and-energy/

animal production and management, additional funding in research and development will be needed in the coming years to compensate for the expected twofold increase in animal products.[12] The impact of these changes on climate change are important research needs. Specific steps to address challenges:

- Increased feed efficiency leads to fewer resources used to produce food with less waste. Expanding on previous NIFA's AFRI funding on feed efficiency in cattle is an example of where to focus resources.[13]
- Improved research into adding enzymes into animals' diet also has the potential to significant contribute to the efficiency of animal production and management.
- There is still work to be done to understand the physiological relationship between the animal and its environment as a basis for designing the physical environment that will optimize both animal well-being and productivity at various stages of the cycle – breeding, gestation, and growth.

- ***Increasing plant and animal health through early and rapid detection of diseases***
  The movement of pests and diseases across the globe needs to be tracked so that they can be countered before they arrive in the U.S. While there are efforts directed at specific diseases, they are often not joined up at the national or international levels.

  Citrus greening (citrus huanglongbing - HLB) is an existential threat to the U.S. citrus industry. Soybean rust, wheat blast, and wheat stem rust are all emerging threats that also have the potential to cause massive losses. In Europe, the current *Xylellafastidiosa*crisis is an example of a plant disease that has crossed national boundaries to decimate olive crops in Italy and Spain.

  In the U.S., the National Plant Diagnostic Network (NPDN) and the National Animal Health Laboratory Network (NAHLN) were both created in response to 9/11 to enhance agricultural security and be able quickly diagnose and respond to plant and animal diseases. With many public health labs (for people) severely overloaded because of the huge demand for COVID-19 testing, some NAHLN labs are adapting in order to use their existing equipment to screen people for COVID. This has increased testing capacity in several states and is helping more people to receive their results more quickly. Both NAHLN and NPDN receive NIFA funding.

  Additionally, the new soon to be in operation National Bio and Agro-Defense Facility (NBAF) in Manhattan, Kansas, will protect U.S. agriculture and food supply against serious animal diseases. Once construction and commissioning activities are complete, USDA's Agricultural Research Service (ARS) and Animal and Plant Health

[12] https://www.nationalacademies.org/our-work/science-breakthroughs-2030-a-strategy-for-food-and-agricultural-research
[13] https://nifa.usda.gov/announcement/researchers-are-working-improve-feed-efficiency-beef-cattle

Inspection Service (APHIS) will conduct foreign animal disease research, training, and diagnostics.

AFRI has a new program, Tactical Sciences for Agricultural Biosecurity within the Foundational and Applied Science Program, that aims to increase national capacity to prevent, rapidly detect, and quickly respond to biological threats to the U.S. agriculture and food supply.

Addressing the vulnerabilities of our nation's food and agricultural system requires a concerted effort, sustained investment, and a coordinated strategy that protects the U.S. food and agriculture system against threats from pests, diseases, contaminants, and disasters. USDA can continue to provide leadership to these extremely essential USDA efforts to better coordinate the Federal government response to emerging threats to the U.S. agriculture and food supply.

In the past year, a Global Surveillance System (GSS) has been proposed[14] to enable countries and regions to quickly respond to emerging disease outbreaks in order to stabilize food supplies and enhance global food protection. While the focus is on low income countries, the engagement of U.S. researchers in monitoring efforts would strengthen the network and provide valuable advance information to U.S. farmers and ranchers.

The current COVID-19 pandemic is a salient reminder that managing animal health is important to avoid zoonotic diseases' spread to humans *via* farm animals. While there are diagnostic laboratories across the U.S., reports of animal disease are coordinated only for pathogens and major diseases. The lack of repositories for many potential pathogens hinders efforts to monitor and control diseases, and study their evolution. There are opportunities for the U.S., primarily managed through ARS, to be linked with international networks so that the spread of global pathogens of potential negative economic impact as well as human health impacts can be tracked before they arrive on U.S. soil. These efforts need to be coordinated with basic animal health and immunology research supported by ARS, NIFA and NSF to guide development of therapies and vaccines for key animals.

3. *For each opportunity identified, answer the following supplemental questions:*
    a. *What might the outcome for the innovation solution (e.g. the physical or tangible product(s) or novel approach) from each of the four innovation clusters?*
        i. Genome Design
        ii. Digital/Automation
        iii. Prescriptive Intervention
        iv. Systems Based Farm Management

[14] Carvajal-Yepes et al. (2019) A global surveillance system for crop diseases. *Science* **364** (6447) 1237-1239. DOI: 10.1126/science.aaw1572

Possible outcomes of innovation solutions were provided in responses to previous questions, with additional input below:

Alternative approaches to current ways working

USDA has an important role to play in funding advances in the key areas described above. It also has the potential to accelerate advances through changes in the way it works by developing nimble, flexible approaches that could allow rapid response where needed. Examples include:

- Effective use of plant and animal synthetic biology tools (knock-ins, knockouts, gene replacement, gene editing) requires development of easily deployed platforms to engineer tens and hundreds of stacked traits into any target rather than focusing on individual traits and organisms. This advance requirement needs systems-level data and models, which should be low cost and widely available. USDA could build access and distribution into its future funding strategies.
- Rapid-response grants and small internally-reviewed grants are needed to support high risk-high payoff research. If these cannot be reviewed internally, then USDA/NIFA could set up an *ad hoc* team of rapid-response reviewers to provide reviews at short notice.
- A flexible fund to support transdisciplinary virtual centers focused on emerging threats such as plant or animal diseases could allow existing research efforts to rapidly refocus when needed.
- Funding could be made available to increase training, knowledge, and resource flow for undergraduate and graduate students, international students, and postdoctoral researchers. USDA, through ARS, NIFA, and the Foreign Agricultural Service's collaboration with the United States Agency for International Development, could provide these additional opportunities that benefit American agriculture industry.
- Many challenges require larger funding than current USDA resources, and are of national and global importance. Public-private partnerships must be developed to avoid duplication with the private sector and extend the impacts of the funding. For animals, one example is the EU Farm Animal Breeding and Reproduction Technology Platform (FABRE-TP)[15], an industry-led forum that promotes partnerships among the public and private sectors across Europe. It has provided input into the upcoming Horizon Europe framework.[16] The Animal Task Force (ATF), a European public-private partnership linking European industry and researchers to promote innovation, has also provided input into Horizon Europe.[17] Many priorities and goals align with U.S. interests. Connection of these types of organization

[15] http://www.fabretp.eu
[16] http://www.fabretp.eu/uploads/2/3/1/3/23133976/atf_vision_paper_2019.pdf
[17] http://animaltaskforce.eu/Portals/0/ATF_Vision_Paper_2019.pdf

to U.S. counterparts could be beneficial in developing seamless strategies for tackling challenges that cross international boundaries.

- International partnerships are also crucial for some efforts, especially plant and animal disease monitoring and identification of new genetic diversity. Partnership with the Foundation for Food and Agriculture Research (FFAR), NSF, Biotechnology and Biological Sciences Research Council (BBSRC), and Bill & Melinda Gates Foundation could be used to achieve this.

b. *What are the specific research gaps, regulatory barriers, or other hurdles that need to be addressed to enable eventual application, or further application, of the innovation solution proposed from each of the four innovation clusters?*

- There is a lack of clearly defined objective measures for sustainability goals, for example, in the area of animal agriculture. USDA has a key role in developing partnerships with the public and private sectors, nationally, and internationally. As a funder, it can promote the adoption of science-based community-developed standards and goals.
- International regulation of gene-edited plant and animal and products are not synchronous with U.S. regulation and there are issues with public perception of safety in some markets.[18] This is a barrier to deployment of some of the proposed advances, since it would negatively impact export markets.
- In the next 20-30 years, USDA needs to build upon current basic research and knowledge. This could be a barrier if basic research isn't expanded upon, but it could also be an opportunity for USDA and agricultural innovation. Basic research provides the needed foundation to allow agricultural innovations to thrive.
- As noted above, there is not sufficient support for training for students and postdoctoral researchers. This barrier is preventing students from gaining needed scientific experience, including data analysis. While USDA, through NIFA's multiple education programs, aims to enhance the agriculture education pipeline, USDA could provide additional direct training, training infrastructure, and leadership through transdisciplinary teamwork across the relevant USDA agencies.
- Slow review and funding cycles slow down research. USDA has the authority to use Intergovernmental Personnel Act employees (IPAs) and could bring in rotators with specialized expertise to speed up review of proposals submitted to special competitions.

[18] https://abiggerconversation.org/wp-content/uploads/2019/09/Gene-edited-Animals-in-Agriculture-Roundtable-Report_27-Aug-2019_Final.pdf