# Table of Contents

Farm Animal Integrated Research (FAIR) 2012 Executive Summary ........................................... 3

Preamble ........................................................................................................................................ 3

Major Focus Areas and Priorities ................................................................................................. 3

Crosscutting Issues ....................................................................................................................... 3

Conclusions .................................................................................................................................. 3

FAIR 2012: Final Synthesis and Introduction of Priorities ............................................................. 4

Summary of Conference Plenary and Breakout Sessions ............................................................... 6

Theme 1: Economic Growth and Environmental Sustainability .................................................. 6

Theme 1: Research and Education Priorities Identified ................................................................. 7

Theme 2: Animal Agriculture in Society and the Global Marketplace ........................................... 7

Theme 2a: Animals in Society ......................................................................................................... 8

Theme 2b: Factors Influencing the Global Marketplace ................................................................. 8

Theme 2: Research and Education Objectives Identified ............................................................... 10

Theme 3: One Health—Healthy Animals, Healthy People, Healthy Planet ................................. 10

Theme 3: Research and Education Objectives Identified ............................................................... 12

Crosscutting Themes Emerging from FAIR 2012 ......................................................................... 13

Strategic Directions of FAIR 2012 ................................................................................................. 13

Focus Area 1: Food Security ......................................................................................................... 13

Focus Area 2: One Health ............................................................................................................. 14

Focus Area 3: Stewardship ........................................................................................................... 14

Crosscutting Issues ....................................................................................................................... 15

Conclusions .................................................................................................................................. 15
Farm Animal Integrated Research (FAIR) 2012
Executive Summary

Preamble
The world population reached 7 billion recently, and global projections suggest 9 billion people by 2050—an astronomical number that will double the need for food and increase competition for limited resources. That competition, combined with climate change, loss of biodiversity, and degradation of resources, will be juxtaposed against the survival of the planet itself. Public investment in research and education is now more critical than ever. Globally, we are all in this together and we need to ensure that the linkages do not break down; the United States must take the lead role. The distillation of information gleaned from the plenary sessions of FAIR 2012 has resulted in three major focus areas, with a number of priority research, education, and outreach objectives. A number of crosscutting issues were also identified that must be considered to ensure success in meeting future challenges. These focus areas and crosscutting issues are presented below.

Major Focus Areas and Priorities

Focus Area 1: Food Security—Maximizing the efficiency of food animal production is necessary to meet global demands for protein.
- Key Topic 1-1: Feed efficiency
- Key Topic 1-2: Energetic efficiency
- Key Topic 1-3: Connecting “-omics” to animal production
- Key Topic 1-4: Reproductive efficiency

Focus Area 2: One Health—Understanding and improving animal health, human health, ecological health, and their interconnections is essential to the survival of the planet.
- Key Topic 2-1: New approaches to vaccine development (or vaccinology)
- Key Topic 2-2: Understanding and controlling zoonoses
- Key Topic 2-3: Improving animal health through feed
- Key Topic 2-4: Improving food safety through disease control and prevention
- Key Topic 2-5: Enhancing the nutritional value of animal food products to meet human nutrient requirements

Focus Area 3: Stewardship—Limiting impacts on natural resources and fostering animal well-being will be important for animal agriculture because the industry has the responsibility to society of providing essential nutrition.
- Key Topic 3-1: Estimation and reduction of greenhouse gas production
- Key Topic 3-2: Flow of nutrients and other potential pollutants from animal production systems
- Key Topic 3-3: Effects of housing systems on animal well-being

Crosscutting Issues
- Balanced portfolio
- Size and scope of funded research projects
- Enhanced collaborations
- Increased public awareness
- Regulations
- Data mining and bioinformatics

Conclusions
One hundred and fifty years after the creation of the United States Department of Agriculture, the agricultural research extension and education system has many successes of which to be proud. Looking forward, scientific achievements in the areas of Food Security, One Health, and Stewardship will be the likely areas by which success of the animal sciences will be measured and the sustained responsible production of food achieved.
At the culmination of a yearlong effort to develop a national forum of scientists, educators, industry personnel, health professionals, and governmental representatives, we find that the premise for finding consensus on research, educational, and outreach priorities remains remarkably similar to that identified in a similar exercise undertaken in 1998 and published in 2002 (FAIR, 2002). At that time, the focus was on scientific animal agriculture, competitive farmers and ranchers, safe and nutritious food, improved animal health, and enhanced environmental stewardship. In 2002, these needs motivated a call for enhanced public investment in research and education to fuel the “creation of industries and export profits that sustain communities and rural economies across the country” (FAIR, 2002). The sights in 2002 were clearly focused on US agricultural issues.

The stakes in 2012, however, and the arena in which those stakes will play out, are vastly different from those identified in 2002. Then, the US economy was strong and growing, and the United States was the leading exporter of animal protein to the rest of the world. Since then, the worldwide economy has faced tremendous challenges. Although the United States is on pace to have record exports of animal protein in 2012, the country no longer leads in all major categories of animal protein exports. At the same time, other countries have expanded their exports and taken a prominent place on the world agriculture stage. The world population reached 7 billion recently, and global projections suggest 9 billion people by 2050—an astronomical number that will double the need for food and increase competition for limited resources.

That competition, in combination with climate change, loss of biodiversity, and degradation of resources (Foley et al., 2011), will be juxtaposed against the survival of the planet itself, and so public investment in research and education is more critical than ever. Pardey and Alston (2010) make a compelling case for agricultural productivity research based on rate of return (benefit:cost ratios of up to 20:1), reduction of food production costs, and greater access to food by the poorest people, who spend the greatest proportion of their income on food. Foley et al. (2011) suggest a number of scenarios by which increased food production and decreased environmental harm from agriculture can co-exist; and Foley (2011) proposes a five-step plan by which we can achieve food production goals while reducing environmental damage. Clearly, the sights in 2012 must be focused globally.

In considering these issues and the provocative talks and discussions that occurred at FAIR 2012, game changers are clearly needed as we propose research priorities for the next decade and beyond. Funding for agricultural research has stagnated due to budgetary challenges and a lack of understanding of the importance of food and the environment. A breakdown in the interconnectedness between livestock and crop production could easily have a disruptive and game-changing impact on public health and societal well-being. Climate change, catastrophic weather events, governmental breakdowns, overzealous precautionary regulations, war, and other societal upheavals are potential contributors. Globally, we are all in this together and we need to ensure that the linkages do not break; the United States must take a lead role in this.

Another major determinant of future success will be our ability to push the frontiers of science. We must challenge our fellow scientists to make new discoveries that will lead to significant advances in meeting the expected demand for meat and dairy products by 2050. We must attend to the pipeline at both the undergraduate and graduate levels to ensure that we meet the scientific and leadership needs for the future. A much deeper understanding of animal biology and postmortem processes, coupled with rapid translation of revolutionary breakthroughs that leads to swift development and immediate adoption of new technologies, is necessary to keep our planet healthy and meet the increasing global demand for animal food products.

Recent work on residual feed intake (RFI) provides evidence of substantial variation among animals in the efficiency with which they use dietary energy, as well as evidence that selection can increase energetic efficiency. We need to understand the underlying physiology more fully and use that understanding as a guide in applying appropriate genetic selection. This comes with two caveats: (1) animals must not become more efficient by becoming fatter; and (2) selection for low RFI may adversely affect immune function.

Many vaccines are less effective than we would like them to be, and advances in vaccinology could lead to more effective vaccines. This is important in the United States but perhaps even more important in the developing world. It may also be especially important in aquaculture. Some applications may not be related to diseases: a current example is immunocastration, but there may be other approaches to use vaccines to alter physiology and productivity.

A balanced approach to funding and conduct of research is also needed. Currently, with the creation of the National Institute of Food and Agriculture (NIFA), huge multidisciplinary grants are the order of the day. Although multidisciplinary and transdisciplinary research is critical, not all sound research adapts easily to the current format for proposals. Funding streams should be considered, and increased funding for agriculture research by agencies other than the USDA is imperative. With the historical rate of return (20:1) on investment in agricultural research, the USDA must examine its funding structure and ensure that the maximum return on investment is not impeded by governmental restrictions.
References


Theme 1: Economic Growth and Environmental Sustainability

The issues surrounding the question of mutual compatibility of economic growth, environmental sustainability, and the ability to feed an exploding population have been highly controversial and hotly debated over the past decade or so. In order for the global economy to grow and prosper on the gross domestic product (GDP) scale, more goods and services are necessary each year; in this country, we need economic growth to ensure that our standard of living continues to increase. On the other hand, there are global considerations, where increases in the standard of living in many countries are directly linked to access to animal protein. The production and distribution of animal protein—with its attendant issues of grain production, water distribution and availability, global climate change, and finite acres of arable land—are among the major issues facing us that must be addressed with new ways of thinking. Beginning with Robert Malthus in the 1700s, many subscribe to the theory that economic growth and sustainability are incompatible. The Malthusian concept was based on the notion that population growth is always exponential, whereas food production is arithmetic. Thus, according to this reasoning, sustainability can only be achieved by population control. Malthus, however, reckoned without the insight that technology would intervene and move food production from the arithmetic to the exponential growth curve. It is thanks to agricultural research funded primarily through the USDA at land-grant universities that the discrediting of Malthus’ theory concerning the question of population growth and sustainability through food production has been possible.

The relationship between environmental quality and economic development is explained by the hypothetical environmental Kuznets curve: as income goes up, environmental health decreases to a point and then improves. With regard to several indicators of environmental health, this inverted U-shaped curve does appear to hold; for example, water and air pollution based on reductions in levels of sulfur dioxide, nitrogen oxide, lead, DDT, chlorofluorocarbons, and so on. However, energy, land, and resource use (the ecological footprint) do not appear to follow the environmental Kuznets curve; that is, these indicators do not decrease with increasing incomes. Greenhouse gases have continued to increase and the degradation of ecosystem services has continued to decrease in developed countries. In addressing the questions of increased food production and environmental sustainability, the focus on improvements in efficiencies in animal production systems is critical. Nontraditional technologies and technologies that have not yet surfaced will drive improvements in animal production efficiency in the future. To paraphrase Albert Einstein, “we cannot solve problems by using the same kind of thinking we used when we created them.” It is imperative that we not rely on past practices or we could be in direct conflict with our desired outcomes.

The challenges that will continue within the animal production sector include

- Air quality;
- Water quantity, quality, and distribution;
- Available land resources;
- Carbon footprint of food production.

Local, state, federal, and international policies and regulations will play key roles in

- Cost structures,
- Development technologies,
- Application technologies, and
- Economic understanding of a combination of the above.

As we evaluate these key factors, we must invest in sound scientific inquiry in order to develop relevant models that can be used to inform future policies and regulations.

A good example of ways in which sound science can inform relevant policies is development of concentrated animal feeding operations (CAFO) regulations by the US Environmental Protection Agency. The tools to measure quality characteristics for environmental concerns continue to become more specialized for specific compounds and allow for more precise units of measurement. Research needs to continue to give regulators and animal producers a much clearer understanding of the multiple reactions and end-product compounds that affect the environment. Research is needed to provide the federal government and industry sound information about compounds that must be measured in real time versus those that can be monitored over time. Data from CAFO monitoring must be aggregated and understood as a whole over the face of animal production. Falling short of this goal will result in misinformed regulations that burden the livestock industry.

Game-Changing Research Is Needed

Going forward, a number of game-changing research areas must emerge as drivers. Systems research and comprehensive management programs must focus on reducing inputs per unit of production output. Efficiencies of animal water and feed utilization, both latent and overt, must be at the forefront. Examples of research to address efficiencies include animal energetics, feedstuff analysis, genetic development for greater digestibility and nutrient delivery, and metabolic and complex biochemical pathways. To accomplish this, our universities and government laboratories must revert to the basic sciences and ask the following questions:

- What is this process or reaction and what could happen if input changed?
• Why does it work this way and what are the biological mechanisms?
• How does this occur and how can its occurrence under these conditions be explained?
• What are the biological limitations of this process?
• What if the catalyst for output per unit of input is enhanced or changed?

Theme 1: Research and Education Priorities Identified

1. A better understanding is needed of the ecological environment of the rumen to improve efficiencies and reduce carbon footprint of livestock production by developing and sustaining rumen microbes that would
   • minimize methane production;
   • control and maximize fermentation based on diet fed;
   • drive optimum nutrient utilization by the animal; and
   • direct cell-specific nutrients.

2. Within monogastric species, it is essential to
   • find ways to provide the animal more complete digestion of the diet fed; and
   • control maintenance expense partitioning of a greater number of nutrients.

3. For all animals, we need a much better understanding, at the cellular level, of environment by genetic (E × G) interaction through
   • improved genomic understanding;
   • use of modern genotyping tools, both conventional and genetically engineered markers;
   • identification of epigenetic components of animal growth and productivity;
   • integrated outcome-based whole-system analysis of animal agricultural sustainability in the environment;
   • accountability across natural resources—soil, water, air;
   • understanding and linking with genetically engineered plant systems and other systems; and
   • knowledge of relationships to crop/forage inputs and outputs.

4. For a better understanding of consumer beliefs and practices, it is critical for agricultural scientists to include more inter-disciplinary efforts in the areas of planning, research, and application of
   • methods,
   • technology developments,
   • business applications, and
   • economic analysis.

5. Because of the disconnect between producers and consumers of food, it is imperative to find ways to close the gap. Research is needed in the areas of
   • food miles versus optimum production areas, and
   • welfare-friendly environments and environmentally friendly practices.

6. In-depth multi-level and multi-faceted data are critical for accurate model development to enhance understanding of, and communications about, animal agriculture. Certainly, this process will be even more complicated in the future, as consumer shifts in expectations under multi-market conditions will occur quickly, and our production systems will struggle with timely recognition and adjustment. These “demand shifters” will be based on, for example,
   • population,
   • income growth,
   • changes in buying power in developing countries, and
   • demographics.

Theme 2: Animal Agriculture in Society and the Global Marketplace

In considering animal agriculture in society in the context of a global marketplace, several themes emerge that illustrate a number of significant disconnects. Some of these are practical (infrastructure or capacity is lacking) or sociological in nature; others are based on a lack of awareness of scientific food production practices, at both the consumer and federal levels. An overarching theme is the need for a systems approach to address animal research in relationship to supply-chain management and ethics in animal agriculture.

The public needs to understand why competition is important to the United States as well as on a global scale; they need to understand food animal production systems and the ways in which those systems ensure the quality of the end product, improve efficiencies, and reduce regulatory costs and burdens. Society needs to understand how reinvestment in agriculture benefits not only them, but also their children and grandchildren in the future. If the United States does not reinvest, we run the risk of losing our infrastructure, which ultimately would severely affect our food production system. Without a ready source
of replacement scientists, the United States and US-based companies will be at an increasing disadvantage in the global competition for new consumers and for maintaining US consumers and employment.

Keeping that in mind, our educational priorities should ensure that students are attracted to, and have opportunities for gaining experience in, animal agriculture. Many agriculture students today come from urban backgrounds, with fewer than 2% of the US population having a farming background. Furthermore, considering the terminology used in political and marketing arenas can help the public better understand policy and funding needs.

In general, the USDA is seen as a credible source of information by the public. For a variety of reasons, however, USDA funding for agricultural research has lagged behind federal funding of agencies such as the National Science Foundation (NSF) and the National Institutes of Health (NIH). Industry commodity groups have attempted to step into the breach to some extent but that is often seen as self-serving. The USDA must step up to defend food production as a vital component of long-term global sustainability and to work to increase funding levels for research in support of that effort.

### Theme 2a: Animals in Society

This sub-theme addressed a wide-ranging and complex set of circumstances and interactions from companion animals that are increasingly too close to people, to livestock and food animals that are increasingly disconnected from people.

**Companion Animals (Primarily Cats and Dogs): Status in Society and Areas for Research and Education:**

1. Increasing focus in animal science departments, used for recruiting for animal agriculture;
2. Tremendous increase in societal emphasis on humanizing companion animals (designation as guardians of pets, naming pets as beneficiaries of wills);
3. Disclaimers in movie credits regarding lack of actual harm to animals in films (this is not the case with simulated deaths of people in those same films);
4. Increase in medical interventions and therapies for pets;
5. Increase in percentage of discretionary income spent on pet needs;
6. Role of companion animals in therapy and residential care scenarios.

**Agricultural Nonfood Livestock (Horses): Status in Society and Areas for Research and Education:**

1. Role of horses as socio-economic drivers in farm and non-farm lifestyles;
2. Role of horses as therapy animals;
3. Horses as a research model for a number of human aging diseases and disorders;

### Agriculture and Natural Resources

Agriculture and natural resources are at the center of 21st century goals, including

1. Increasing global agricultural productivity;
2. A growing global population in a closed system;
3. A recognition of links between local and global food security, health, poverty, and social/political stability;
4. Increased demand per capita for food, water, fiber and energy—tradeoffs loom large; technologies for improving efficiencies.

### Societal Shifts

1. Increased call for decreasing the environmental footprint of production;
2. Competition for energy sources and feedstuffs for alternative energy production;
3. Increased attention to animal well-being and welfare, leading to regulation of process;
4. Historical identity of product;
5. Increased purchasing power for nontraditionally produced products.

### Theme 2b: Factors Influencing the Global Marketplace

**Trade Barriers**

1. Reduction in choice of goods
2. Increased prices and price security
3. Focus has to be, globally, expanding our goods and services availability without political intervention

**Traceability**

1. The ability to trace history, application, and/or location of a product that is received or is considered for shipment, by recorded identification.
2. Traceability has to be focused on the key words “traced” and “followed.”
3. More research is needed to further define the words “traced” and “followed,” as they are not totally or clearly defined in language outlined in the Internal Organization for Standardization (ISO) or Codex Alimentarius.

Research Investment and Infrastructure

1. Education
   a. Early-career training relative to all aspects of animal research.
   b. Training must include understanding the economics of the respective research.

2. Demand
   a. Understanding of the supply/demand of the end product of the research.
   b. Understanding both the scientific and public opinion views of the research.

3. Cultural differences
   a. Understanding the change in global demographics relative to consumer demands.

4. Flexibility of change/product change
   a. Today’s US consumer is very driven by convenience; thus, feature products have to focus on convenience, not quality, taste, or economics.
   b. The lifespan of products may be shortened by changing demands; thus, new and improved changes of products will be the norm, not the exception.

Internal Relationships and Internship

1. Provide professional training for young scientists.
2. Foster global competency.
3. Reinforce academic training via practical application (based on local practices).
4. Organizational relationships and international opportunities must be focused on the notion that education must influence people’s lives beyond the boundaries of our classrooms or laboratories.

Animal Welfare and Well-Being

1. Differentiate between welfare and well-being.
2. The animal sector must serve as stewards of animals.
3. Continued training must occur within the disciplines of welfare and well-being as they relate to all aspects of animal production.
4. A unified set of guidelines based on sound science.

Increasing Exports While Decreasing Imports

1. Maintaining an optimum “balance of trade.”
2. If our industry exports more product, especially value-added product, the industry will be receiving more dollars from abroad than it is sending abroad.
3. It is imperative that tariffs are monitored, because if tariffs are placed on goods, consumers and businesses will reduce the amount spent on the goods. Other countries may place tariffs on US goods, and thus exports will fall.

Research Investments in Other Countries (China’s $475M budget)

1. US direct investments of animal agricultural research relative to animal production, from basic to applied sciences, including processing, must focus on additive factors to what is conducted in the United States.
2. The focus for this research investment is to serve foreign markets, not to produce products for export back to the United States.
3. Economic research is needed to demonstrate that US investments in other countries are not harmful to US workers due to job shifts to these countries.

Perceptions of Agriculture in the United States

1. Combat the proliferation of conflicting information and misrepresentations that are found in abundance on the Internet and in media circles with “elevator speeches” that are easy to understand but based on sound science.
2. More sound and accurate science delivered by social media, YouTube, School Tube, and so on, coming from reputable people.
3. It is imperative that research be conducted to find ways to reduce the disconnect between farmers and consumers, including the value chain.

Primary Message from Developing Countries

The rising demand for livestock products in developing countries presents significant opportunities:

1. Pathway out of poverty and malnutrition;
2. Less vulnerability in dry lands; and
3. Sustainable mixed systems.
Theme 2: Research and Education Objectives Identified

1. Total systems sustainability.
2. Malnourishment of obesity and malnourishment of hunger.
3. Should USDA fund sociological research?
   a. Sociological/ethical questions (not eating animals or starving the world)
   b. Sociological training in animal agriculture graduate programs
5. Improved efficiencies of production: Discovery research—pathways and genes needed to make the next advances in efficiencies.
7. Understanding the role of companion animals in society, including benefits to mental and physical health.
8. Introduction of food production into K-12 curricula as a parallel to focus on the environment.
9. Tradeoffs of the increased demand per capita and globally for food, water, fiber, and energy.
10. Delivery mechanisms for outreach and education, particularly in developing countries: consider text messaging, Twitter, or other social media that do not rely on computers or electricity.
11. Funding for graduate stipends to enable increased numbers of domestic graduate students to enter the scientific and leadership pipeline in agriculture.
12. Partnerships of industry with groups outside their comfort zone; much of this partnership has to be communicated based on sound science, but also shared values.

Theme 3: One Health—Healthy Animals, Healthy People, Healthy Planet

Society is in a state of flux, with increasingly complex interactions between humans, animals, and the environment, not only within countries but also globally. There are significant threats to the long-term sustainability of life on Earth as we look toward the need to increase food production without destroying the life-support systems on which we all depend. The intensification of animal production as part of this transformation may, if not properly carried out, contribute to land degradation through overgrazing, reduced soil fertility, erosion, and desertification. Proper land-use planning and utilization, taking into account the diverse agricultural, topographic, and geographic aspects involved, is essential to reducing the risk of adverse ecological developments while increasing productivity and disease control. The concept of a One Health integrated approach toward ensuring that we can meet those challenges provides us with unique opportunities to ensure the long-term health of the planet and those that inhabit it.

In order to meet the new challenges to human, animal, and environmental health, we must employ new strategies in an integrated approach, fully realizing that we live in a very large, intricately connected ecological system. We need science-based policy approaches to improve human and animal nutrition and health; guide effective interventions to improve wellness; and ensure an abundant, safe, and secure food supply. To meet this need, it is imperative that rising scientists be well and broadly trained and able to work together in interdisciplinary and transdisciplinary ways.

Core strengths must come from among disciplines such as

- Animal science
- Food science
- Veterinary science
- Human science
- Genetics
- Social sciences
- Engineering

Expertise within these and related fields must include

- Biomedical nanotechnology and translational discovery
- Structure and cell biology and biology and disease management and wellness
- Food safety and security, nutrition and wellness
- Bio-informatics and computational biology
- Plant and soil health
- Infectious disease
- Risk assessment and risk communication

Why is risk analysis necessary? On a daily basis, farmers and ranchers are confronted with an ever-changing landscape of price, yield, and other outcomes that affect their financial returns and overall welfare. The consequences of decisions or events are often not known with certainty until long after those decisions or events occur, so outcomes may be better or worse than expected. Risk assessment involves
the identification of potential human health hazards, the assessment of the level of exposure by humans to these hazards, and the evaluation of the relationship between exposure and response in humans. Research is currently underway to improve the scientific basis of risk assessment through the incorporation of new technologies such as transgenic animals, molecular epidemiology, toxicogenomics, alternatives to animal models, and mechanism-based mathematical modeling into the estimation of risk in a quantitative manner.

- Regulatory science

**Animal and Human Health Issues**

The One Health concept directly addresses a report by the Institute of Medicine (National Academy of Sciences, Institute of Medicine: Microbial Threats to Health, Emergence Detection, and Response, 2003; http://www.nap.edu/openbook.php?isbn=030908864X) that a group of factors have simultaneously converged to create a “perfect microbial storm.” According to the report, the most important factors include:

- adaptation of microbes,
- global travel and transportation,
- host susceptibility,
- climate change,
- economic development and land use,
- human demographics and behavior,
- a breakdown in communication between public and animal health infrastructures, and
- poverty and social inequity.

On this backdrop are overlaid the following factors:

- Zoonoses are often diseases of major economic and public health importance.
- Zoonoses account for 58% of the currently recognized human pathogens; of the annually emerging zoonotic infectious disease events, domestic animals account for 20%.
- Nearly 50% of the global population live in rural areas.
- In both developed and developing countries, people share their home environments with a variety of animal species ranging from companion animals to livestock.
- Poor sanitation and hygiene conditions lead to frequent exposure of humans to animal pathogens, and vice versa.
- Veterinary services and human health care are often limited.
- Because less than 2% of the US population is involved in animal agriculture, zoonoses resulting from direct contact with farm animals are often limited to farmers, veterinarians, and other animal handlers.
- However, numbers of companion animals (dogs, cats, horses) have increased tremendously and zoonoses transmitted by companion animals is increasing; this is exacerbated by the belief by many that “animals are people, too” and the often too-close physical interactions between pets and people.

One substantial aspect of disease prevention and human health is *sound nutrition.* The importance of good nutrition is central to preventing disease, correcting physiological imbalances, and providing energy.

As an example of a comprehensive assessment of research needs linking applied nutrition and human health issues, the National Dairy Council has identified gaps in scientific knowledge that include the following:

- Relationships between healthy weight, body composition, and metabolism
- Understanding relationships between dairy consumption and blood pressure
- Understanding the role of milk fat and its effect on cardiovascular disease
- Understanding the value of dairy protein
- Understanding the relationships between dairy products and digestive health
- Establishing and maintaining databases on food components and nutrition, food regulation, labeling, and trade.

**Environmental Health**

Proper land-use planning and utilization, taking into account the diverse agricultural, topographical and geographic aspects involved, is essential to reducing the risk of adverse ecological developments while increasing productivity and disease control. Optimum health of humans, animals, and the environment is thus tightly linked to good nutrition and sound nutrient management. As the global population begins to exceed 7 billion, the intensification of animal production may, if not properly carried out, contribute to land degradation via overgrazing, reduced soil fertility, erosion, and desertification.
Theme 3: Research and Education Objectives Identified

As understanding of disease mechanisms and human behavior increases, incentives for adopting best practices must follow:

1. On-farm disease research:
   - Determine practices that reliably reduce the probability of initial outbreaks (e.g., bio-exclusion measures) on farms;
   - Determine measures that facilitate early detection, on-farm containment of disease outbreaks, and eradication (e.g., continuously monitor strategic physiological measurements such as noninvasive temperature recordings in group or individual setting);
   - Develop research strategies to mitigate disease impact (e.g., preventive vaccination in high-risk areas).

2. Zoonotic diseases in farm and companion animals: detection and eradication before microbes jump to humans.

3. Developmental programming and genetics (and epigenetics) of animal disease relationships.


5. Climate and demographic changes in relationship to disease challenge.

6. Improve emergency preparedness and response plans.


8. Efficiencies of protein production relative to environmental inputs and effects.

Crosscutting Themes Emerging from FAIR 2012

The data backbone of agriculture is weak because we have not been able to maximize utilization of solid historical and ongoing accumulating data. As research priorities are set and agendas announced, it is imperative that comprehensive mining of historical data be conducted. Data mining will reveal information that can be converted into knowledge about historical research and these historical data can be used to predict future trends to be used in research planning to support guidelines and policies. Data mining would uncover enormous amounts of information relative to the effects of animal products versus carbohydrates, for example, on health, growth, and obesity. Messages from many groups about animal products continue to be negative, despite substantial evidence to the contrary; a systematic mining and synthesis of existing sound scientific data would refute the false allegations.

We must understand that funding is the biggest obstacle to addressing research priorities. Agricultural research is a low-cost source of future agricultural output, but advances in the frontiers of science are difficult and uncertain, translating into long lags. With mean lags of 15 to 20 years, agricultural productivity cannot be jump-started after a long period of stagnant investment in public agricultural research. With funding delays, world food prices will rise more rapidly than otherwise projected during the next 40 years (CAST Commentary: Investing in a Better Future Through Public Agricultural Research; CAST_QTA2011-1, March 2011; http://www.cast-science.org/publications/?investing_in_a_better_future_through_public_agricultural_research&show=product&productID=2963). The USDA has severely eroded its support of agricultural research over the last 20 years, resulting in a parallel erosion in consumer confidence and a loss of global reliance on US products. Meanwhile, China and others are “ramping up” funding for agricultural research; a situation that will produce strong game changers worldwide.

Another crosscutting theme is the social acceptance of animal food products, which, although currently high, may be hijacked by misinformation. There is a need to invest in effective crosscutting communication strategies, led by agricultural communicators who are trained. A focus on youth as a target audience was identified for maximizing the efficiency of utilization of valuable feedstuffs.

A tremendous confounding aspect of agricultural research has been caused by the withdrawal of federal support by the USDA, forcing scientists to look for funding in other venues, notably industry. This has resulted in the very damaging perception by members of the public that investigators have been “bought” or are “in the pocket of” for-profit interests. Although patently untrue, perception is often reality in the minds of the largely uninformed and disconnected public. Ironically, federal agency funding is viewed by most as being unbiased, despite the restrictions on federal scientists from speaking publicly on the science of issues if contrary to the official dogma.

Strategic Directions of FAIR 2012

It is imperative that the United States not relent in its support of the food and agricultural sciences. The world looks to the United States as a global vendor of food, and, in that role, we dare not neglect the environmental footprint of food production and delivery systems based on sound science.

The distillation of information gleaned from the plenary sessions of FAIR 2012 has resulted in strategic directions aimed to address the imminent challenges society will experience in the face of an expanding global population. Three major focus areas, with a number of priority research, education, and outreach objectives, and a number of crosscutting issues, were identified that must be considered to ensure success in meeting future challenges. These focus areas and crosscutting issues are provided below.

Focus Area 1: Food Security

One of the greatest challenges facing animal agriculture will be to meet the increased food needs of a growing global population. It is estimated that the world’s population will reach 9 billion by the year 2050, and global food production will need to double in order to meet these food demands. The Food and Agriculture Organization of the United Nations (FAO) projects that 70% of this doubling will have to occur through the development and adoption of new technologies. The FAO estimates a 73% increase in meat consumption and a 58% increase in dairy consumption worldwide by the year 2050. Much of this increased consumption will come from developing countries, where people are emerging from poverty and demanding improved diets.

In order to meet increasing demands in a sustainable way, food producers must continue to increase the efficiency with which they use limited natural resources, placing a premium on increased production efficiency in animal agriculture. Compounding the challenge of increased production with limited resources is the diversion of food and feed crops into bioenergy, effectively taking land and resources out of the food security equation. All of these factors point to the need for increased investments in science to increase production capacity and efficiency.

Global food production must increase dramatically during the coming decades because of both a projected increase in the human population and an exhilarating improvement in the purchasing power of many poor people in developing countries, which will increase demand for foods of animal origin. Meeting that increased demand within the constraints of the earth’s resources will require substantial improvements in the efficiency of use of resources. The expected increase in demand for foods of animal origin makes especially imperative a marked improvement in efficiency of use of valuable feed resources in animal production. There are important opportunities to achieve such improvements through research. The contribution of animals to global food security depends heavily on maximizing the efficiency of utilization of valuable feedstuffs.
• **Key topic 1-1: Feed efficiency**: Includes nutritional and management factors affecting the efficiency of feed utilization in farm animals, encompassing the full life cycle; considers measurement of dietary energy, factors affecting digestibility such as feed processing and use of exogenous enzymes, and other items.

• **Key topic 1-2: Energetic efficiency**: Includes genetic and other factors affecting energetic efficiency in animal tissues.

• **Key topic 1-3: Connecting “–omics” to animal production**: Includes functional genomics, proteomics, metabolomics, epigenetics, and their practical applications in animal production.

• **Key topic 1-4: Reproductive efficiency**

**Focus Area 2: One Health**

With increases in globalization, the intersection between animal and human health continues to become more and more complex. The One Health concept has evolved in recent years in response to these increased complexities. In its broadest sense, One Health addresses factors affecting animal health, human health, ecological health, and their interconnections, using an interdisciplinary approach. One example of these interconnections is the impact of zoonotic diseases. Zoonoses (diseases that can be passed between animals and humans) are often diseases of major economic and public health importance and account for 58% of currently recognized human pathogens. Of the annually emerging zoonotic infectious disease events, domestic animals account for about 20%. Further complicating this situation is the fact that, in both developed and developing countries, people share their home environments with a variety of animal species, ranging from companion animals to livestock. Poor sanitation and hygiene conditions lead to frequent exposure of humans to animal pathogens and vice versa.

The intersection of human and animal health is also fertile ground for policy and regulatory challenges. For example, the use of antibiotics in animal agriculture has been the source of much controversy in recent years as critics express concerns about antimicrobial resistance. Investments in research will be essential to more clearly understand these issues and provide decision makers with science-based information to develop better-informed policies.

Sound nutrition is another critical aspect to disease prevention and improving human and animal health. The importance of good nutrition is central to preventing disease, correcting physiological imbalances, and providing needed energy. Healthier animals also provide safer and more wholesome products for human consumption. Advances in the animal sciences can play a major role in promoting the One Health concept, resulting in healthier humans, animals, and the environment.

• **Key topic 2-1: New approaches to vaccine development**

• **Key topic 2-2: Understanding and controlling zoonoses**

• **Key topic 2-3: Improving animal health through feed**: Includes feed additives, feed ingredients, and other aspects of feed that may influence immune function, microbiota of the digestive tract, and animal health.

• **Key topic 2-4: Improving food safety through disease control and prevention**

• **Key topic 2-5: Enhancing nutritional value of animal food products to meet human nutrient requirements**

**Focus Area 3: Stewardship**

Animal agriculture touches many aspects of our society: providing essential nutrition, balancing natural resources, and fostering animal well-being. In order to meet global food demands in a sustainable way, investments in science will be critical to increasing the efficiency with which limited natural resources are utilized. Water quality and quantity are major issues, as competition for this precious resource intensifies. Society also continues to have concerns about climate change and the impacts that animal production may have on climate. These factors demonstrate the need for increased investments in science.

Great successes in resource use efficiency have already been realized through technological innovations. For example, in analyzing the life cycle of beef production between 1977 and 2009, the same amount of beef can now be produced with 10% less feed energy, 20% less feedstuffs, 30% less land, 14% less water, and 9% less fossil fuel energy. Improvements in production systems have also led to an 18% decrease in total carbon emissions. In light of the need to double food production by 2050, science must keep pace with population growth to make even greater strides in resource utilization.

Another important factor of stewardship is animal well-being. Critics of animal agriculture continue to raise concerns about the effects that production systems and increased production capacity have on the well-being of farm animals. Housing systems for farm animals are evolving in response to societal concerns and market demands. Standards for housing and production systems must be based in sound science, and investments are needed to better understand these issues.

• **Key topic 3-1: Estimation and reduction of greenhouse gas production**: Includes refinement of estimation of the carbon footprint of animal production systems, rumen function, efficiency of feed use, production systems and other items.

• **Key topic 3-2: Flow of nutrients and other potential pollutants from animal production systems**: Includes quantification within an animal production system, but also extended to whole farm systems including crop/forage production; and post-harvest.

• **Key topic 3-3: Effects of housing systems on animal well-being**
Crosscutting Issues

Increased investments in the priority areas identified by FAIR 2012 will be critical for the animal sciences and animal agriculture to successfully meet the challenges of Food Security, One Health, and Stewardship. However, increased investment alone will not be enough. A number of crosscutting issues must also be addressed to help ensure success:

Balanced Portfolio – One of the strengths of the US agricultural system is the “three-legged stool” of research, education, and extension. It is critical that this balanced approach be maintained. Support for research should span from fundamental to applied, with adequate resources dedicated to the extension of these technologies into the field. It is also important to maintain the capacity of both intramural and extramural programs. The educational component must not be neglected because the success of animal agriculture depends on a robust pipeline to develop new scientists, producers, and industry professionals.

Size and Scope of Projects – A current trend at the USDA is to fund large, multi-institutional grants over extended periods. Although there is value in these large awards, it is important to maintain a balance in the size and scope of projects. Without such balance, there is a risk that research driven by single investigators or new investigators will be neglected because of inadequate resources. This could have the unintended consequence of driving new scientists away from agriculture, further jeopardizing the development of new leaders in the animal sciences.

Enhanced Collaborations – Enhanced collaborations on issues important to the animal sciences can play an important role in meeting future challenges. The USDA, universities, and others should increase links with federal research agencies such as the National Institutes of Health, National Science Foundation, Department of Energy, and others to leverage limited resources and drive innovation.

Increased Public Awareness – Animal agriculture suffers from a perception problem. A critical need exists to better inform consumers about the importance of farm animal production and the value of agricultural research.

Regulations – The issues surrounding animal agriculture are fertile ground for regulations, including issues related to the environment, animal drugs, and trade. The future success of animal agriculture will depend on the consistent and predictable use of sound science by policy makers.

Data Mining – As research priorities are set and agendas developed, it is important that comprehensive mining of historical data be conducted, to understand what is already known, to prevent unnecessary duplication, and to provide a better base on which to build future research. Data mining will reveal information that can be converted into knowledge about historical research, and these data can be used to predict future trends to be used in research planning to support guidelines and policies.

Conclusions

One hundred and fifty years after the creation of the United States Department of Agriculture, the agricultural research, extension, and education system has many successes of which to be proud. Looking ahead, scientific achievements in the areas of Food Security, One Health, and Stewardship will likely be the areas by which success of the animal sciences will be measured. Increased public investment in the priorities identified by FAIR 2012 will be important in feeding an increasing global population in a way that maximizes the efficient use of limited resources and promotes human, animal, and ecological health. To achieve the greatest impact of these investments, attention must be paid to crosscutting issues related to the structure of research programs, enhanced collaborations, science-based policies, and increased public awareness of the importance of animal agriculture and the role of science. There is no doubt that the challenges facing animal agriculture in the future will be significant but, with wise investments in science, success is achievable.
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