National Program 101 – Food Animal Production Action Plan (2007-2012)

Background

The Agricultural Research Service (ARS) is the intramural research agency for the U.S. Department of Agriculture (USDA), and is one of four agencies that make up the Research, Education, and Economics mission area of the department. The ARS budget is allocated to research conducted in 22 national program areas. Research is conducted in 108 laboratories by ~2,200 full-time scientists within a total workforce of ~8,000 ARS employees. The ARS national program addressing animal production is NP 101 – Food Animal Production. NP 101 involves research conducted at 20 U.S. locations by 102 full-time scientists and has an appropriated budget of approximately $46.5 M per annum.

U.S. systems of agricultural animal management and production face formidable challenges. One of the most exacting challenges is successful adaptation to the accelerating demands of society that impact animal productivity and product quality. The demands placed on the national system of food animal production by a rapidly changing world can only be met by technologies that optimally harness the inherent genetic potential of animal and plant germplasm in concert with certified industry and food marketing practices. Production systems that successfully identify, preserve, and harness that genetic potential will maximize profits, secure supply, increase market competitiveness, sustain small and mid-sized producers, and maintain genetic diversity and consumer confidence.

The vision for this national program is *"to furnish scientific information about biotechnologies and management practices that ensure an abundant supply of competitively priced animal products"*. Consequently, the overall mission is to: 1) safeguard and utilize animal genetic resources, associated genetic and genomic databases, and bioinformatic tools; 2) develop a basic understanding of the physiology of livestock and poultry; and 3) develop information, tools, and technologies that can be used to improve animal production systems, all to ensure an abundant, safe, and inexpensive supply of animal products produced in a healthy, competitive, and sustainable animal agriculture sector of the U.S. economy. This National Program mission follows from the USDA/ARS Strategic Plan (see http://www.ars.usda.gov/aboutus/docs.htm?docid=1766) which, in turn, is directed towards achieving goals mandated by the USDA Research, Education, and Economics Mission Area Strategic Plan and the USDA Strategic Plan (see http://www.usda.gov/ocfo/usdasp/usdasp.htm).

The products of research conducted in this national program contribute toward broader goals associated with four specific Performance Measures from the ARS Strategic Plan.

Goal 1: Enhance Economic Opportunities for Agricultural Producers.

Performance Measure 1.2.1: Provide producers with scientific information and technology that increase production efficiency, develop improved germplasm, safeguard the environment, improve animal well-being, and reduce production risks and product losses. Target: Specific information and technology will be available to food animal producers for evaluating animal productivity and well-

being, increasing efficiency, and decreasing environmental impact through improved management models and reproduction methods.

Performance Measure 1.2.2: Develop needed information on the relationships between nutrients, reproduction, growth, and conversion to and marketability of animal products. Target: Information will be available to producers for more efficiently converting improved knowledge about the interactions of reproduction, growth, and nutrient intake to increase marketability of food animals.

Performance Measure 1.2.3: Identify genes responsible for economically important traits, including animal product quality, efficiency of nutrient utilization, and environmental adaptability. Target: Better understanding will be available of how genes are responsible for economically important traits in food animals, such as nutrient utilization and environmental adaptability.

Performance Measure 1.2.4: Maintain, characterize, and use genetic resources to optimize and safeguard genetic diversity and promote viable, vigorous animal production systems. Target: The diversity of food animal germplasm will be maintained and optimized to invigorate production systems.

Linkages with Other ARS National Programs

Research projects in the Food Animal Production National Program are inter-linked to activities in a number of other ARS national programs which either directly or indirectly impact animal agriculture. These programs include NP 103 (Animal Health); NP 104 (Veterinary, Medical, and Urban Entomology); NP 106 (Aquaculture); NP 205 (Rangelands, Pastures, and Forages); NP 206 (Manure and Byproduct Utilization); and NP 108 (Food Safety).

Linkages with USDA-CSREES National Programs

Research projects in this ARS national program are also coordinated with research, education, and extension programs administered by USDA's Cooperative State Research, Education, and Extension Service (CSREES). This process was first facilitated by co-hosting of a Joint USDA-ARS/CSREES Stakeholder Planning Workshop for the national program area of Animal Production and Well-Being held in April 2006. The activities of the ARS NP 101 research program are directly inter-linked with activities in the CSREES national program areas of: 1) Genetic Improvement of Animals and Animal Genomes; 2) Reproductive Performance of Animals; 3) Nutrient Utilization of Animals; 4) Animal Physiological Processes; 5) Environmental Stress in Animals; 6) Animal Management Systems; 7) Improved Animal Products (Before Harvest); and 8) Animal Health and Protection. Furthermore, these programs are all further coordinated with the goals and funded research programs affecting animal production within the National Research Initiative Competitive Grants Program of CSREES.

Component 1: Understanding, Improving, and Effectively Using Animal Genetic and Genomic Resources

To meet preferences and needs of consumers for animal products while effectively utilizing the natural resource base, livestock and poultry are produced in a wide array of environments and management systems. Insufficient quantitative and genomic characterization of existing genetic resources compromises efficiency of production across climactic zones of the U.S., limiting optimal use of feed resources and response to disease threats. Losses in production efficiency from genotype by environment interactions and gene by gene interactions must be better understood to respond to these challenges and increase profitability. Existing genetic resources provide producers with numerous options that can be tailored to meet current and future demands. However, several of these resources are at risk of being lost, even before they are adequately characterized. Germplasm conservation efforts require a wide range of information and analytical tools.

Genetic improvement of livestock and poultry populations is a key strategy for increasing efficient production in an ethically responsible manner. The rate of improvement, however, is hindered by lack of data on some economically important traits, inadequate understanding of quantitative and molecular genetic controls of component traits and interrelationships among traits, less than optimal methods for evaluating candidates for selection, and inefficient strategies to incorporate genomic data in to breeding programs. This includes the ability to move novel forms (alleles) of genes between populations.

Comprehensive knowledge of the genome and its interactions with environmental factors is required to fully understand the biological basis of all animal and poultry science disciplines. Acquiring new knowledge in a “systems biology framework”, pertaining to animal adaptation and well-being, reproductive efficiency, nutrient utilization and conversion to animal products, and product quality, will be significantly enhanced with appropriate genomic tools and reagents. Continued public involvement in the construction of these resources is critical to ensure development of economically feasible management tools for livestock producers and to provide all researchers access to these tools and reagents to spur forward technology development for transfer to industry as quickly as possible.

Problem Statement 1A: Develop Genome-Enabling Tools and Reagents.

Significant public resources have been devoted to developing genomic and bioinformatic infrastructure for the important livestock and poultry species over the past two decades. These efforts have culminated in significant improvement in the genomic information on these species available in the public domain, yet, considerable work remains to bring the poultry (chicken and turkey), and livestock (bovine, porcine, ovine, caprine, and equine) genomes to a level of information content necessary for optimal “mining” through functional genomic and proteomic approaches. ARS remains committed to devoting the necessary resources to fill these research gaps.

Research Needs:

ARS research will contribute to the development of annotated genome sequence assemblies of the chicken, bovine, and porcine genomes (minimum 7-fold

coverage). These annotated genome assemblies will also be highly valuable for informing the physical maps of the ovine, caprine, turkey, and equine genomes through comparative genomic approaches. Haplotype maps of the chicken, bovine, and porcine genomes are required to speed fine mapping of quantitative trait loci (QTL) and evaluate the potential for whole genome selection for complex quantitative traits. A full and comprehensive array of full-length cDNAs is required for functionally important tissues under differing environmental conditions and developmental stages to ascertain alternative splicing of genes and to fully explore gene function and regulation. Further development of gene expression tools to a commercially available level are required to fully facilitate functional genomic and genetical genomics approaches. ARS should further develop resource populations for these species that provide an optimal framework for mining genomic information. Furthermore, work is needed in the development and study of specialized cell lines from food animals that can be used to study gene expression through the use of tools such as RNA interference and targeted gene transfer. Fundamental research is needed to further develop methodology for transfer of genes within and across species. Finally, significant gaps exist in the minimum bioinformatic infrastructure required to facilitate rapid access to and visualization of livestock and poultry genomic and proteomic data by the research community on a routine basis.

Anticipated Products:

- Annotated genome sequence assemblies of the chicken, bovine, and porcine genomes.
- Densely populated haplotype maps of the chicken, bovine, and porcine genomes.
- Improved physical and genetic linkage maps of the ovine, caprine, equine, and turkey genomes.
- Full-length cDNA libraries and gene expression tools spanning important tissues, environments, and developmental stages for the important livestock and poultry species.
- Well-characterized and deeply phenotyped resource populations of dairy cattle, beef cattle, swine, and sheep.
- Specialized cell lines enabling the study of gene expression.
- Improved techniques and methodologies for intra- and inter-species gene transfer.
- Improved bioinformatic tools for rapid, routine access to and visualization of genomic information.

Potential Benefits:

The completion of these genome-enabling tools and reagents is the foundation upon which continued genetic and managemental improvement of livestock and poultry systems relies. These tools will be used to develop new genetic selection methodologies, identify the functional role and interactions of gene products in the interactome of the animal, and ultimately to develop “precision genetic management systems” for livestock and poultry. These tools will not only be used for traditional animal production research applications (reproduction, growth and development, nutrient intake and utilization, product quality), but will also be

used to decrease the environmental footprint of animal production, improve animal health, well-being and resistance to disease, and enhance food safety.

Problem Statement 1B: Identify Functional Genes and Their Interactions.

The development of initial genetic linkage maps for the livestock and poultry species quickly led to whole genome scans for the detection of chromosomal regions (Quantitative Trait Loci, QTL) harboring genes contributing to the variation observed in economically important production traits. A large pool of QTL have now been identified for a variety of traits including growth rate, components of reproductive efficiency, and product yield and quality attributes; yet only a relative few of these QTL have been elucidated to the genic (Quantitative Trait Nucleotide, QTN) level. Additionally, QTL have yet to be identified in a significant way for complex traits that have been more difficult to describe in genetic models. Such traits include efficiency of nutrient utilization, reproductive capacity and longevity, various animal behaviors, and genetic resistance to stress and disease.

Research Needs:

Post-sequencing genomic architectures will be used to fine map existing QTL for livestock and poultry production traits in chickens, dairy and beef cattle, and swine. Considerable research effort is required to develop and validate the measurement of relevant phenotypes for components contributing to the complex traits of efficiency of nutrient utilization, reproductive capacity and longevity, animal well-being and resistance to stress, and product quality. Identification of QTL for these traits is a high priority which will eventually lead to the identity of genes impacting these traits and how they may be regulated genetically, epigenetically, and environmentally.

Anticipated Products:

- Valid standardized phenotyping systems for determination of genetic and phenotypic variation in efficiency of nutrient utilization, reproductive capacity and longevity, animal well-being and stress resistance, and product quality.
- Identification of QTL for efficiency of nutrient utilization in livestock and poultry.
- Information relating the function and regulation of individual genes contributing to economically relevant traits in livestock and poultry.
- Development of DNA-based diagnostics to provide genotypic information for use in centralized genetic evaluation and improvement systems.
- Further contribution to the annotation of the genome sequence of livestock and poultry species.

Potential Benefits:

Information generated from the research conducted in this area will form the basis for inclusion of genotypic data in national genetic evaluation programs. Functional genomics data will serve as the cornerstone for enablement of systems biology research. Development of a more complete understanding of

the biological systems underpinning livestock and poultry performance will ultimately lead to a precision livestock and poultry production management framework. Production of animal products will become more energy efficient, have lessened environmental impact, and be from animals with enhanced well-being and welfare. Ultimately, the impact of this research work will be to enhance profitability and economic competitiveness of U.S. livestock and poultry producers.

Problem Statement 1C: Preserve and Curate Livestock and Poultry Genetic Resources.

Maintenance of genetic diversity in populations of livestock and poultry is critical to the long-term competitiveness of animal agriculture. Considering the trends of the past several decades toward increased consolidation and integration of production, along with employment of breeding systems that accumulate inbreeding within breeds and lines, this need has risen to highest priority. Furthermore, due to increased concentration of livestock and poultry, and continued increase in the easy and rapid movement of animals, the need exists to be able to respond to repopulation of animal and poultry systems in the event of a widespread disease outbreak or other catastrophe that would threaten the genetic resource base of animal agriculture.

Research Needs:

Selection of specific germplasm to be preserved requires phenotypic and genetic characterization for a wide variety of phenotypic characteristics measured within the appropriate production environments and systems. Genetic diversity characterization of individuals within breeds and lines should be performed using a suite of tools, including carefully designed genomic evaluations using appropriate high-throughput DNA marker systems (eg. single nucleotide polymorphism (SNP) panels). Such a process will allow minimization of redundancy while insuring complete coverage of germplasm diversity. Considerable gaps exist in the ability to preserve gametes and embryos of the various livestock and poultry species, with the need for improved cryopreservation technologies being most critical in poultry. The need exists to select, catalog, and curate DNA and other tissue-based collections of germplasm for both research and germplasm conservation purposes. Finally, the bioinformatics platform (Germplasm Resources Information Network, GRIN) interfacing the database of the nation's livestock and poultry genetic resources held in the National Animal Germplasm Program should be further developed to make information quickly and readily accessible, as well as become effectively linked to other such resources around the world.

Anticipated Products:

- A broad spectrum of genetic diversity in the form of viable and well-documented livestock and poultry germplasm conserved.
- Genomic diversity in conserved populations ensured via the use of molecular technologies in selection of individuals to be preserved.
- Successful and efficient cryopreservation technologies and methods available for all livestock and poultry species.

- DNA and other tissue banks in place for research and genetic resource preservation purposes for livestock and poultry species.
- High-quality, comprehensive characterization, evaluation, and Genbank curatorial data made readily accessible, either from a transformed, upgraded, well-maintained GRIN, from databases housed at GRIN as the primary site, or at sites linked to GRIN.

Potential Benefits:

Careful strategic planning for and successful implementation of genetic resource management projects will provide industry users with a more dependable and more diverse source of high quality livestock and poultry genetic resources. In particular, vulnerable or threatened genetic resources will be better preserved and more secure. The National Animal Germplasm Program will be a repository of the alleles being elucidated in the post-genome sequencing era so that they may be available for long-term use by the animal agriculture industry in responding to the needs of the future. Readily available access to comprehensive and curated germplasm characterization information will allow strategic use of livestock and poultry genetic resources in fulfilling the demands for animal products in the future.

Problem Statement 1D: Develop and Implement Genome-Enabled Genetic Improvement Programs.

Application of quantitative genetics theory to populations of livestock and poultry has resulted in significant directed genetic change in particular components of performance, primarily from the use of field data recorded in both public and private national schema. Much of this improvement was facilitated by the maturation of statistical methodology coupled with increased scope and power of computing platforms that could be applied to large-scale pedigreed phenotypic data sets. Genetic evaluation and improvement programs are now poised to jump to new plateaus with elucidation of genetic parameters and interrelationships among traits, development of objective multi-trait breeding goals, and the availability of genomic resources for characterization at the individual gene and gene sets level. Additionally, the focus of genetic improvement programs is now shifting from production-driven to animal well-being and functionality-driven strategies.

Research Needs:

The suite of traits included in genetic evaluation programs of livestock and poultry is in need of expansion beyond the traditional production traits. Specifically, research to describe genetic parameters for a suite of economically important traits including efficiency of nutrient utilization, reproductive capacity and longevity, animal behavior, and resistance to stress is needed. These parameters include direct and maternal breed and heterosis effects, heritabilities, and genetic, phenotypic, and environmental correlations. As new traits continue to be defined and added to the genetic evaluation pipeline(s), continued work to define breeding objectives incorporating information from multiple traits under specific production-marketing environments is warranted. Work in functional genomics and proteomics will yield new diagnostics and genetic evaluation tools regarding specific genes and gene complexes. This new molecular information

must be incorporated in to genetic evaluation and prediction frameworks in order to maximize genetic improvement. Additionally, new approaches to holistically use molecular information from the entire genome at the haplotype map level, must be investigated and validated to determine if and how they can be employed in genetic selection and mating programs. The complexity of the new types of information becoming available for genetic evaluation and improvement will require significant advances in statistical methodology and software to effectively put such data to practical seedstock industry use.

Anticipated Products:

- Genetic prediction for a suite of new traits in livestock and poultry related to adaptability and functionality in production-marketing environments.
- Enhancement of genetic evaluation and breeding system design for economically important production traits in livestock.
- Validation of new whole-genome selection methods for genetic improvement programs.
- Development of technologies allowing producers to identify genetic inputs fitting breeding objectives defined within their specific production-marketing environment.
- Statistical tools and methodology for incorporating molecular genetic data into genetic evaluation and prediction programs, resulting in “genome-enabled” genetic improvement.

Potential Benefits:

Enhancement of genetic improvement programs by adding traits which enable producers to better match genetic potential to the production resource base and consumer and societal demands will lead to a more profitable and sustainable animal agriculture. Genomic-level information will allow complex traits previously excluded from genetic improvement to be evaluated, these traits include many of the most important to enterprise profitability. Identification of elite genetic seedstock at younger ages with higher levels of inherent accuracy will allow the rate of genetic change to accelerate to previously unattainable levels. Much of the value of previous public research investments in animal genomics will be realized through “genome-enabled” genetic improvement programs resulting from this research.

Component 1 Resources:

Eighteen (18) ARS projects that are coded to NP 101 address the research needs identified under Component 1. ARS scientists who are either partially or fully assigned to these projects include:

Location:	***Scientists:***
Beltsville, Maryland	M. Bakst, L. Blomberg, J. Cole, E. Connor, D. Donovan, L. Gasbarre, D. Guthrie, J. Long, M. Kuhn, R. Li, G. Liu, D. Norman, M. Richards, T.

	Sonstegard, N. Talbot, P. VanRaden, C. Van Tassell, R, Wall, G. Wiggans, Vacancy (AIPL).
East Lansing, Michigan	H. Cheng, H. Hunt, H. Zhang.
Clay Center, Nebraska	M. Allan, G. Bennett, E. Casas, R. Cushman, L. Cundiff, C. Ferrell, B. Freking, H. Freetly, G. Harhay, T. Jenkins, J. Keele, K. Leymaster, D. Nonneman, G. Rohrer, S. Shackelford, T. Smith, W. Snelling, G. Snowder, M. Thallman, J. Vallet, D. Van Vleck, T. Wheeler, R. Wiedmann, Vacancy (NRU), Vacancy (GBRU).
Fort Collins, Colorado	H. Blackburn, P. Purdy.
Miles City, Montana	L. Alexander, T. Geary, M. MacNeil, A. Roberts.
Dubois, Idaho	Vacancy, Vacancy.
Athens, Georgia	R. Barb, G. Hausman.
Brooksville, Florida	C. Chase, D. Riley.
Booneville, Arkansas	D. Brauer, J. Burke, M. Looper.

Component 2: Enhancing Animal Adaptation, Well-Being and Efficiency in Diverse Production Systems

Livestock and poultry production are considered value-adding industries to various agricultural input commodities as well as land resources considered marginal for crop production. Production systems operate in a wide range of physical and marketing environments from a highly diverse natural resource base. Proper matching of animal genotype and management system to the production-marketing environment is critical for sustainable and profitable production. This requires a comprehensive understanding of factors affecting animal adaptability and functionality, well-being, and efficiency.

The development of scientific measures of stress and well-being and an enhanced ability to interpret such measures is crucial to the evaluation of current animal agriculture management practices and development of improved alternatives. Stress caused by social, nutritional, and environmental factors and their interactions need to be understood to limit negative impacts on care, production efficiency and well-being. Society is now demanding that scientific standards for documenting animal welfare within industry production systems become a critical control point in quality assurance programs.

The major cost contributing to unit cost of production in the livestock industry is the maintenance of the breeding herd or flock. Two limiting factors hinder reducing this cost: 1) reproductive rate per breeding female, and 2) the relatively high energy cost required for maintenance of the breeding herd. Furthermore, longevity of breeding females is an

important contributor to lowering cost of production (i.e. increased longevity is desirable due to the high cost of producing replacements), yet, in several of the livestock industries the average age of breeding females has been declining in recent years, reflecting a loss of longevity.

Successful and efficient reproduction is essential to food and fiber production from livestock and poultry. Numerous environmental factors compromise reproductive success and contribute to decreased breeding longevity. Seasonal infertility in swine and reduced conception rates in cattle breeding programs are particular areas of concern. Sub-optimal embryonic, fetal, and neonatal development and survival significantly contribute to reduced reproductive efficiency in several of the species.

Feeding and nutritional regulation of cells and organs jointly affect every aspect of livestock and poultry production. Animal industries are challenged to efficiently produce livestock products and to balance growth, feed consumption, and management of waste products. Given that upwards of 60% of total energy costs in the livestock and poultry industries are in feed inputs, it is imperative that solutions be found to allow improved efficiency of nutrient utilization for conversion to animal and poultry products.

Problem Statement 2A: Enhance Animal Well-Being and Reduce Stress in Livestock and Poultry Production Systems.

Recent food industry trends reflect a growing concern in the American public regarding animal welfare in food production systems. These concerns have resulted in a new set of supply system requirements from a number of major animal product customers for certification of specific animal care, production, and transport guidelines. It is unlikely that this trend will diminish in the near-term future. The livestock and poultry industries need to have clear and interpretable scientific criteria developed to allow proper assessment of animal well-being to meet these consumer demands in the marketplace. These criteria must be developed and validated within standard industry production systems. Development of such criteria will require a much improved understanding of stress physiology and animal ethology. The ultimate goal is to identify means for enhancing animal well-being through identification of improved production management practices that are profitable and sustainable for producers.

Research Needs:

Research is needed to further develop and refine scientific criteria for measuring animal welfare within production systems by comprehensively utilizing endocrine and immunological biomarkers in combination with animal behavioral and production performance data. A more complete understanding of the physiological, immunological, and behavioral responses of livestock and poultry to various stressors is needed to allow strategies to be developed to reduce production risk and losses. Specific research data are needed to address pre-weaning piglet losses, gastric ulceration, aggression, and sow welfare in swine production systems. Improvement of production systems to reduce neonatal calf morbidity and cow lameness is needed in dairy production systems while stress imposed by weaning, transportation, and co-mingling as well as from heat stress and fescue toxicosis are areas of needed focus in commercial beef production systems. Housing related issues encompass the primary need areas of poultry

production including delineation of appropriate space, thermal, and lighting requirements, and a better understanding of feather pecking and aggression in birds. Research is also needed to consider the impacts and alternatives to beak trimming as well as to reduce lameness in laying hens and broilers. Forage and secondary metabolite induced equine conditions, including laminitis and fescue toxicosis, are not well documented or understood. A more complete understanding of the relationship between various animal temperaments, innate and adaptive immunity, and productivity is needed for all livestock and poultry species.

Anticipated Products:

- Scientific criteria for the assessment of animal welfare in livestock and poultry production systems.
- Enhanced understanding of physiological and behavioral response of livestock and poultry to environmental stressors.
- Improved management practices and production system designs that maintain or enhance productivity while improving animal well-being targeted to specific priority animal welfare issues.
- Identification of means to increase longevity of breeding animals.

Potential Benefits:

Animal stress and well-being research will benefit animals, producers, and ultimately consumers, by ultimately identifying means for reducing animal health-care costs and improving food production efficiencies. Achievement of these economic and societal goals will help maintain and increase demand for livestock and poultry products in domestic markets and become more competitive in world markets, particularly in light of rapidly changing requirements for animal production practices in the international sector.

Problem Statement 2B: Reducing Reproductive Losses.

Increasing reproductive rate has been a goal of livestock and poultry research for the last several decades but has been largely unrealized in ruminants while only modest gains have been achieved in non-ruminants. Reproductive capacity and longevity is a complex trait and is affected by a number of environmental factors including temperature, humidity, photoperiod, and plane of nutrition. Managing the production environment for optimum reproductive efficiency requires an understanding of basic neuro-endocrine regulatory mechanisms, gonadal and uterine function, and development of the conceptus. These systems may be further altered by other environmental factors including social interactions among animals, handling by humans, housing, and transportation. Prepubertal development, seasonally reduced gamete production, postpartum anestrus, and aging all represent periods of reproductive inefficiency in livestock and poultry. Opportunities exist to optimize economic returns by determining how to combine genetic and nutritional resources in a manner that reduces the duration of these periods of reproductive quiescence. Delays in establishing pregnancy increase cost and reduce output of food animal systems. Maximum production efficiency requires every fertilized egg to result in birth of a healthy offspring

that survives and grows during the neonatal period. Factors contributing to embryonic and fetal losses and/or inappropriate development in domestic livestock are only partially understood. Incidence of embryonic and fetal mortality has been estimated to be 20 to 40% in livestock species and 10 to 14% in poultry. Collectively, significant improvement of reproductive efficiency will require a true "systems biology" approach to be successful.

Research Needs:

Data to elucidate the impacts of environmental stressors on successful gamete production, fertilization, and pregnancy resulting in live births are needed for all livestock and poultry species. Research to address the observed decline in conception rate per service in dairy cattle as well as research to identify the physiology underlying seasonal infertility in swine should be conducted. Data to address how to reduce the prevalence of small litter sizes in swine are needed as well as research to better predict male fertility at early ages. Research to identify contributing factors and underlying physiology responsible for embryonic and neonatal losses in swine, cattle, and sheep is warranted. Physiological factors underlying lowered longevity of breeding females must be elucidated to address this issue in cattle and swine. Research to better understand the relationship of fescue pasture systems with cattle, small ruminant, and equine reproductive function is needed in the transition zone of the U.S. Finally, maternal epigenetic and behavioral effects on neonatal survival should be investigated.

Anticipated Products:

- Identification of critical control points limiting improvements in reproductive rate in livestock and poultry.
- Data to facilitate appropriate matching of management and production resources with genetic potential of breeding animals with the goal of increasing reproductive rate.
- Improved management practices and systems for improved reproductive success across production systems and environments.
- Identification of physiological means for reducing seasonal infertility in swine.
- Recommended production practices and management alternatives for increasing non-return rate in dairy cattle.
- Strategies based on physiological data for increasing longevity of breeding females in livestock systems.

Potential Benefits:

Increasing reproductive capacity and longevity of the nation's breeding herds of livestock and poultry will lead to a more stable and profitable animal agriculture primarily by reducing production risks and losses. By spreading overhead costs associated with maintenance of breeding herds and flocks over more output per individual, production efficiency and profitability should be concurrently increased. Optimization of management and human and natural resources with genetic potential of breeding animals has the greatest potential payoff in animal production systems in this arena.

Problem Statement 2C: Improving Efficiency of Nutrient Utilization and Conversion to Animal Products.

The single largest cost of livestock and poultry production lies in feed inputs. Enhancement of nutrient utilization, therefore, is one of the major pathways toward improvement of production efficiency. A number of research priority areas exist in this area, including:

1) Livestock and poultry improvement programs continue to rapidly change genetic merit for production, particularly for rate of growth and yield of meat, milk, and eggs. Specific nutrient requirements and feeding systems must be determined and validated to allow the realization of these higher levels of genetic potential while minimizing nutrient losses to the environment. A comprehensive understanding of the metabolic or physiological functions that limit production potential is required to achieve this goal. As the genomes of livestock and poultry species are annotated, opportunities are increased for using functional genomics to develop an understanding of the regulation of genes and gene complexes by specific nutrients.

2) A major controlling factor of growth and development across species is feed intake. Feed costs represent the primary economic input into livestock and poultry production systems. Metabolic and sensory factors affect short-term feeding behavior. Long-term feeding behavior is controlled by the animal in its attempt to achieve a defined equilibrium within its environment. Understanding mechanisms involved in regulating feeding behavior and appetite should lead to more efficient production of livestock and poultry.

3) Ruminants rely on diverse microflora to digest feeds while monogastrics also host microbial populations in their gut that can influence efficiency of nutrient use. However, past research in microbiology of the rumen and other gut environments has barely scratched the surface of understanding the composition, function, and dynamics of these communities. Mathematical tools and new technologies emanating from the genomics revolution (i.e. metagenomics) provide exciting opportunities to delve deeper in to this area. Enhanced understanding of rumen microbiology also may provide insight in to applications to the area of bioenergy production.

4) Ethanol and biofuel production is rapidly increasing in the U.S., with current estimates predicting that over 20% of corn supplies will be used for ethanol production by 2010. This shift in the availability of feedstuffs for livestock and poultry production, along with the concurrent increase in byproducts from biofuel production, will require attention to the development of nutritional regimens under lower energy diet systems.

5) A substantial portion of the livestock production in the U.S. relies on forage-based systems. In recent years, there has also been a growing trend toward development of pasture-based dairy and beef production systems. Effective utilization of forages by livestock suffers from a lack of adequate understanding of rumen digestion of forages in mixed diets, an incomplete understanding of the characteristics of forage plants that alter nutrient digestibility, inability to

deal with toxicosis problems from some forages, and inadequate methodology for evaluating feed characteristics and digestibility.

Research Needs:

Research to utilize the chicken, cattle, and swine annotated genome sequences to develop an understanding of the regulation of genes and gene complexes by nutrients needs to be undertaken. Developing an understanding of metabolic syndromes in cattle through this approach is also warranted. Work to better understand feed intake in poultry and cattle should be conducted including identification of genes and gene products affecting feed intake and how they may be regulated by specific nutrients. Knowledge gaps exist in how feed efficiency may be altered in beef cattle, particularly in understanding genetic effects. Means of increasing the efficiency of nitrogen utilization are lacking and need further development in cattle and swine. Metagenomics, community fingerprinting, and PCR-based population assessments to characterize the rumen and other gut microbial ecosystems is warranted. Gaps exist in the ability to optimally utilize forage-based systems for dairy and beef production including an incomplete understanding of: 1) plant characteristics and factors limiting digestibility; 2) digestive physiology; 3) transformation of nutrients and factors affecting the partitioning of nutrients into end products from digestive fermentation; 4) animal physiological response to fescue toxicosis; 5) methodology for describing the relevant characteristics of forages including digestibility, physically effective fiber, starch, non-fiber carbohydrates; and 6) year-round forage-beef finished systems. Finally, critical research is needed to determine the nutrient requirements of genetically-enhanced livestock and poultry in combination with genetically-enhanced feedstuffs. This includes research to address the changing composition of production diets due to the increase in the biofuels sector of the U.S. economy.

Anticipated Products:

- Precision feeding systems for livestock and poultry that optimize nutrient availability to the animal while minimizing nutrient losses to the environment.
- Updated and current nutrient requirement tables for enhanced feedstuffs and increased genetic potential for production of animals and poultry.
- Optimization of lower energy diets in poultry and swine.
- Development of refined methodology allowing precise nutrient evaluation of forages.
- A demographic picture of the rumen and other gut environments.
- A “gene atlas” for feed intake, animal metabolism, and effects of various feed nutrients.
- Nutritional and production-management strategies for reducing the incidence of metabolic imbalance in cattle.
- Strategies to reduce the negative effects of fescue toxicosis in grazing livestock.
- Determination of the degree of genetic control of feed efficiency in cattle.
- Optimized year-round forage-based finished beef systems.

Potential Benefits:

Research in this area will allow the development of precision management livestock and poultry systems that make optimal use of nutrient inputs in both intensive and extensive production environments. Better understanding of genetic regulation will lead to the development of nutritional modulators that increase efficiency of nutrient use. Improved nutrient utilization will allow improved use of natural resources and will lower the environmental footprint of animal agriculture. Development of forage-based and other less-conventional production systems opens up new value-added market opportunities for mid-sized and small livestock producers. Improved understanding of the digestive environment will lead to applications to enhance gut fermentation, including potential applications to other processes including bioenergy production.

Component 2 Resources:

Twenty (20) ARS projects that are coded to NP 101 address the research needs identified under Component 2. ARS scientists who are either partially or fully assigned to these projects include:

Location:	***Scientists:***
Beaver, West Virginia	W. Clapham, J. Neel.
Ithaca, New York	J. Russell.
Beltsville, Maryland	M. Bakst, R. Baldwin, L. Blomberg, T. Caperna, E. Connor, T. Elsasser, D. Guthrie, C. Li, R. Li, J. Long, J. McMurtry, A. Mitchell, T. Ramsay, M. Richards, R. Rosebrough.
Madison, Wisconsin	G. Broderick, M. Hall, R. Hatfield, N. Martin, D. Mertens, R. Muck, P. Weimer.
West Lafayette, Indiana	H. Cheng, S. Eicher, J. Marchant-Forde, D. Lay.
Clay Center, Nebraska	M. Allan, T. Brown-Brandl, R. Cushman, S. Echternkamp, R. Eigenberg, C. Ferrell, J. Ford, H. Freetly, B. Freking, T. Jenkins, J. Klindt, J. Miles, J. Nienaber, G. Snowder, J. Vallet, R. Wiedmann, C. Williams, T. Wise, Vacancy (NRU).
Miles City, Montana	L. Alexander, T. Geary, E. Grings, M. MacNeil, A. Roberts, R. Waterman.
Lexington, Kentucky	G. Aiken, R. Dinkins, M. Flythe, I. Kagan, J. Strickland.
Starkville, Mississippi	S. Branton, W. Dozier, H. Olanrewaju, S. Purswell, W. Rouse.

Dubois, Idaho	G. Lewis, J. Stellflug, B. Taylor.
Athens, Georgia	R. Barb, G. Hausman.
Brooksville, Florida	C. Chase, S. Coleman, D. Riley.
Booneville, Arkansas	D. Brauer, J. Burke, M. Looper.
El Reno, Oklahoma	M. Brown, H. Mayeux, B. Phillips.
Lubbock, Texas	J. Carroll, S. Dowd, Vacancy.

Component 3: Measuring and Enhancing Product Quality

The primary goal of animal agriculture is to provide consistently uniform, high quality and nutritious foods to the consumer. Consumer demands, however, are not static and production systems must evolve to meet marketplace preferences. For example, as consumers demand foods lower in fat content, animal production systems respond with changes in breeding, nutrition, and management to deliver such products. A growing sector of the consuming public is demanding animal products from less intensive and non-conventional production systems including grazing dairy and beef finishing systems and organic animal production systems. Product consistency and quality from these systems is as yet relatively poorly characterized. American consumers have a wide array of readily available food products, resulting in stiff competition amongst the sectors of the food industry. New information is continually needed to provide food animal producers with the tools to continue to develop innovative products that meet processor and consumer needs.

Problem Statement 3A: Developing Systems for Reducing Variation in Product Quality and Yield.

Survey data at the processor, purveyor, and retail marketing sectors of the food industries continually point to lack of product consistency as a major concern in the beef, swine, and small ruminant industries. Many defects in quality are only noticed by the consumer, when it is unfortunately too late to take corrective action. Processors require non-invasive, non-destructive testing procedures to identify defects and measure product yield and quality characteristics. Objective measures and systems for determining product value characteristics should allow processors to more effectively communicate value differences to producers and give producers greater incentive to improve product quality and consistency. Such “value feedback” will facilitate the development of coordinated supply chains which effectively apply all available known tools to guarantee improved product quality and consistency.

Research Needs:

Continued research which attempts to better understand the biological basis for product quality attributes, including tenderness, flavor, juiciness and other important organoleptic properties of meat is needed across all muscle cuts in beef, pork, and lamb. Product variation introduced by various animal stressors

has begun to be described and needs further attention. Research to develop techniques and instrumentation for the assessment of product yield and quality under commercial meat industry conditions is warranted.

Anticipated Products:

- Identification of supply chain critical control points which can be targeted for increasing product quality.
- Validated methodologies and instrumentation for on-line commercial industry use to determine product quality and yield.
- Profiling of factors contributing to product quality differences on a by-muscle group basis.

Potential Benefits:

Results of the research conducted in this area will facilitate the further development of value-based supply chains in the beef, swine, and small ruminant industries. Technology based on science to increase product quality and consistency will further reduce the risk experienced by livestock producers and will provide a means to enhance the profitability and sustainability of the U.S. livestock industry.

Problem Statement 3B: Characterization of Products from Non-Conventional Production Systems.

Increasing attention has been given in the past decade to the development of niche livestock and poultry markets based on more extensively managed production systems. While a variety of these systems exist in animal agriculture, a prevailing theme amongst them is a return to previously used animal husbandry systems that make extensive use of pasture-based forage systems and/or require certified organic production practices. While some research studies have been conducted to evaluate the characteristics of products from these systems, there is generally a lack of consensus in the research literature regarding the resulting comprehensive product nutritional profiles from them. Additionally, society is demanding information concerning the quality and safety of animal products derived from bioengineered animals, including clones produced by somatic cell nuclear transfer as well as recombinant DNA animals (i.e. transgenics).

Research Needs:

Data are needed that comprehensively characterize the product yield and quality attributes of meat, milk, and egg products from pasture-based and organic animal production systems. The most critical needs exist in the areas of grazing dairy systems and year-round grass-finished beef systems. These research data are needed across the diverse seasonal and regional production system parameters required to meet year-round supply chains. Data are needed on the characteristics of products derived from bioengineered animals (somatic cell nuclear transfer clones and their progeny, transgenic animals).

Anticipated Products:

- Scientific documentation of the nutritional value of products resulting from grass-finished beef systems and how these profiles may be affected by environmental (seasonal) and managemental factors in the production system.
- Identification of critical control points that define how production management systems should be operated to ensure the meeting of consumer preferences for these products.
- Scientific data to be used in the decision-making process regarding use of bioengineered animals in animal production systems.

Potential Benefits:

Research in this area will provide foundational scientific data upon which producers can develop and implement supply chains to meet consumer demands for these products on a regional basis. This will allow small and mid-sized land managers to contribute to new markets and thereby provide a sustainable and profitable return on their properties. Finally, data will be available upon which to make science-based decisions regarding the regulation of food animal products from bioengineered animals (clones and transgenics).

Component 3 Resources:

Five (5) ARS projects that are coded to NP 101 address the research needs identified under Component 3. ARS scientists who are either partially or fully assigned to these projects include:

Location:	*Scientists:*
Beaver, West Virginia	W. Clapham, J. Neel.
Beltsville, Maryland	L. Gasbarre, A. Mitchell, J. McMurtry, M. Richards, R. Wall.
Clay Center, Nebraska	S. Shackelford, T. Wheeler, Vacancy (MRU).
Dubois, Idaho	G. Lewis, B. Taylor, Vacancy.
El Reno, Oklahoma	M. Brown, H. Mayeux, B. Phillips.