USDA
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Antimicrobial Resistance
ACTION PLAN

United States Department of Agriculture

As the Co-Chairs of the USDA One Health Joint Working Group, we are pleased to present the USDA Antimicrobial Resistance (AMR) Action Plan. This plan takes advantage of the strengths of our existing activities. In addition, it describes an approach that will allow us to address recognized knowledge gaps and develop effective, practical mitigation strategies that will help prolong the effectiveness of antibiotics to treat both people and animals. The action plan describes how the USDA proposes to obtain and disseminate science-based, actionable, information about antibiotic drug use, its potential role in the development of antibiotic resistance in food-producing animals, and the relationship of drug use and resistance patterns to livestock management practices.

Throughout our action plan, we emphasize the integration of activities across the USDA. Our current work in AMR has made important contributions to our understanding of AMR. However, these activities are best described as "patchwork," and their lack of integration has limited the overall results of our investments. To achieve the greatest impact, we recognize that resources must be coordinated and expertise leveraged across USDA agencies. We also acknowledge that implementing these activities will require the help of our Federal, industry, and academic partners.

We will continue to perform our existing activities using currently available funding and resources. However, the new activities we propose for the future cannot be accomplished within the constraints of existing funding levels. A limitation in our ability to fully implement this action plan is the deficiency of dedicated, long-term funding for these activities. We will continue to seek additional funds to enact these new policies.

This USDA Antimicrobial Resistance Action Plan outlines our current activities and proposes a comprehensive, integrated approach for future surveillance; research and development; and education, extension, and outreach activities. By fully funding and implementing this plan, the USDA will continue to play a major role in addressing recognized knowledge gaps and in developing effective, practical mitigation strategies for use in animal agriculture that will help to prolong the effectiveness of antibiotics to treat both people and animals.

We look forward to working with you to implement this action plan.

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Executive Summary

Antimicrobial resistance is considered one of the most serious health threats to both animals and humans. The One Health concept recognizes that the health of humans and animals is irrevocably linked and closely connected to the environment. Antimicrobial resistance (AMR) is an issue that requires a One Health approach. It is a multi-faceted issue that everyone has a shared responsibility in limiting its impact.

Even though the United States Department of Agriculture (USDA) is not the lead regulatory agency with respect to antibiotic use and AMR, USDA is an important part of the solution to address this challenge. For nearly two decades, the USDA has been actively involved in surveillance, basic and applied research, and education and outreach to assess levels of AMR, develop effective mitigation strategies for AMR, and assist animal producers to implement these strategies. USDA activities have made important contributions to understanding the role of animal production in AMR and to reducing its development and spread. However, considerable work remains, and there is a growing sense of urgency to address this problem.

This action plan describes how USDA proposes to obtain and disseminate science-based, actionable, quantitative antibiotic drug use information coupled with the development of resistance in food-producing animals and to relate this to livestock management practices. With the help of Federal, industry, commodity, and academic partners, USDA proposes to address recognized knowledge gaps and develop effective, practical mitigation strategies that will help to prolong the effectiveness of antibiotics to treat both people and animals.

This action plan outlines USDA's current activities and proposes a voluntary comprehensive, integrated approach for future surveillance; research and development; and education, extension, and outreach activities that span three objectives:

Objective 1: Determine and/or model patterns, purposes, and impacts of antibiotic use in food-producing animals.

Objective 2: Monitor antibiotic drug susceptibilities of selected bacterial organisms in food-producing animals, production environments, and meat and poultry.

Objective 3: Identify feasible management practices, alternatives to antibiotic use, and other mitigations to reduce AMR associated with food-producing animals and their production environments.

USDA possesses in-depth knowledge of the management practices and technologies associated with animal health, welfare, productivity, and food safety. As such, USDA is uniquely positioned to contribute to the body of scientific knowledge about AMR, specifically about the role of antimicrobial use in livestock. The successful execution of this action plan would provide and disseminate science-based information to the veterinary and animal agricultural communities so they can implement effective mitigation strategies that will help to prolong the effectiveness of antibiotics for use in both animals and people.

Introduction

The One Health concept recognizes that the health of humans, animals, and the environment is intimately connected. Antimicrobial resistance (AMR) is an example of a challenge that will require a One Health approach. Simply stated, there is concern that bacteria that cause disease in both people and animals are developing more resistance to the antibiotics[1] used for treatment. Some believe that the use of antimicrobial drugs in agriculture is one of the primary drivers for the emergence of AMR. In reality, our understanding of the factors that contribute to levels of AMR in various settings and the specific role of antimicrobial use in agriculture in the selection for AMR bacteria is incomplete.

The public health and veterinary communities have implemented actions to encourage the judicious use of antimicrobials in people and animals. Judicious use of antibiotics is an integral part of good veterinary and production practices. It is an approach that maximizes therapeutic efficacy and minimizes selection of resistant microorganisms. The Food and Drug Administration's (FDA) guidance for antibiotic use is provided in "Judicious Use of Medically Important Antimicrobial Drugs in Food-Producing Animals" (FDA Guidance #209). However, FDA's efforts to support good antimicrobial drug stewardship in agriculture have been hampered by a lack of science-based data on antimicrobial use linked to observed AMR in animals.

Challenges to Addressing AMR

The ecology of antimicrobial resistance is extremely complex. This impacts our ability to understand and prevent the selection and spread of AMR. The development and spread of AMR does not just involve the use of antimicrobial drugs in humans or food-producing animals.

The ecology of antimicrobial resistance is extremely complex. This impacts our ability to understand and prevent the selection and spread of AMR. Simple solutions are not sufficient to address such a complex problem.

Since the beginning of time, the soil microbiome has produced natural antimicrobials, and bacteria have developed unique mechanisms (i.e., resistance genes) to resist their inhibitory or killing effects. This natural exposure and continual evolution of resistance continues today in the ecological system. Not only is the environment intimately linked with both humans and food-producing animals, but also our activities, such as disposal and transport of human sewage and animal waste, impact soil and water and, in turn, the ecology of antimicrobial resistance (See figures A and B in Appendix 3).

At the same time, other species also interact with the environment and contribute to the transmission of antimicrobial resistance. Domestic and wild animals, birds, fish, and insects can transport bacteria, including resistant strains, to other locations. This movement creates opportunities for animals or people to acquire bacteria. There are many pathways among people, animals, and the environment connecting resident bacterial populations in one population or setting to those in other populations or settings. This continuum is constant on the global scale. Indeed, no place on Earth is excluded from this cycle as recent studies have demonstrated the presence of bacteria caught in wind streams at 30,000 feet, which likely moves bacteria across the globe.

The ability of bacteria to move from one setting to another, sometimes over large geographic distances and among the different populations, makes it difficult to know with certainty where resistant strains of bacteria originated. Adding even more complexity, bacteria also have the ability to share their genetic material with other bacteria in a variety of ways. Resistance genes can be inherited by the next generation of bacteria resulting from cell division or they can be shared horizontally among bacteria in close physical proximity. This further complicates our ability to understand the ecology of AMR (See figures C and D in Appendix 3).

Clearly, simple solutions are not sufficient to address such a complex problem. As the example in figure D illustrates, antibiotic resistance is a multi-faceted issue. Everyone involved in animal production or public health, and even the consumer, has a shared responsibility to limit the impact of antimicrobial resistance.

Role of the USDA and Partner Agencies in Addressing AMR

The United States Department of Agriculture plays a dual role in the protection of animal production and public health. As such, USDA is a key partner in establishing the One Health concept, particularly concerning AMR. USDA is responsible for performing residue testing at slaughter but has no other regulatory authority pertaining to antibiotic use in animal production.

[1] In this plan, the terms antimicrobial drug and antibiotic are used interchangeably; however, antimicrobial drugs are a broader category since they have activity against more than just bacteria and include synthetic medications such as sulfonamides.

The Food and Drug Administration is the primary regulatory agency for antibiotic use in animals. The FDA determines which antibiotics are safe for use in livestock and poultry and establishes appropriate conditions of use. However, USDA and FDA work together closely to identify and mitigate emerging threats to America's food supply. For example, under the U.S. National Residue Program, USDA's Food Safety and Inspection Service (FSIS) samples meat, poultry, and egg products for antibiotic residues, and FDA takes enforcement actions on FSIS-determined violations. USDA has collaborated and provided recommendations to FDA on "Guidance for Industry #213," the most recent guidance regarding the judicious use of medically important antibiotics and proposed revisions to the veterinary feed directives. Perhaps most significantly, the FDA relies on the science-based information that USDA generates about antibiotic drug use, AMR patterns, and livestock and poultry management practices to inform its policy and regulatory decisions. FDA also taps into USDA's extensive network of collaborative relationships with producers and animal agriculture industry organizations as part of its outreach.

Although USDA is not the lead regulatory agency with respect to antibiotic use and AMR, USDA is a part of the solution to address these challenges through partnerships with stakeholders and via the missions of several key agencies. Each USDA agency—the Agricultural Research Service (ARS), the Animal and Plant Health Inspection Service (APHIS), the Economic Research Service (ERS), the FSIS, the National Agricultural Statistics Service (NASS), and the National Institute of Food and Agriculture (NIFA)—plays a different role in addressing AMR,and these actions are described in Appendix 4. USDA employees possess in-depth knowledge of the management practices and technologies associated with animal health, welfare, productivity, and food safety.

For nearly two decades, USDA has been actively involved in surveillance, basic and applied research, and education and outreach to assess levels of AMR, to develop effective mitigation strategies for AMR, and to assist animal producers to implement these strategies. These activities have made important individual agency contributions to understanding the role of animal agriculture in AMR and to minimizing its selection and spread. However, these efforts lacked integration and prioritization at the departmental level. This has ultimately limited their overall impact. USDA recognizes that considerable work remains, and there is a growing sense of urgency to address this problem. Through this action plan, USDA describes a roadmap for a comprehensive, integrated approach to develop effective, practical mitigation strategies for animal agriculture to help prolong the effectiveness of antibiotics used to treat people and animals.

Beyond partnerships within USDA and with the FDA, the Department also regularly collaborates with other Federal agencies, such as the U.S. Department of Health and Human Services' Centers for Disease Control and Prevention (CDC) and the National Institutes of Health (NIH). USDA is a member of the Interagency Task Force on Antimicrobial Resistance (ITFAR), which was created in 1999 and is co-chaired by the CDC, FDA, and NIH, and includes a broad range of Federal partners. The Task Force developed a comprehensive document, A Public Health Action Plan to Combat Antimicrobial Resistance, which reflects a broad-based consensus by Federal agencies on actions needed to address antimicrobial resistance (**available at www.cdc.gov/drugresistance/actionplan/actionplan.html**). This action plan provides a blueprint for specific, coordinated actions to address antimicrobial resistance. USDA also played a major role in establishing the National Antimicrobial Resistance Monitoring System (NARMS) with the FDA and CDC and remains an active collaborator in the program. The USDA also partners with academic institutions, as well as international universities, government agencies, and industry. These global connections ensure harmonization of methods and access to information of emerging trends prior to their arrival in the United States.

In May 2012, USDA sponsored a workshop[2] with stakeholders, Federal partners, and USDA agency staff to review current antibiotic use and resistance monitoring, management practices to reduce antibiotic resistance, and alternatives to the use of antibiotics to treat and prevent diseases or to enhance production in food-producing animals. This workshop identified important knowledge and data gaps, and participants encouraged USDA to develop an integrated, strategic plan to address them.

[2] Documents from this workshop can be found online at: **www.ars.usda.gov/research/programs/programs.htm?np_code=103&docid=17547.**

USDA's Action Plan to Address Antimicrobial Resistance

This action plan describes how USDA proposes to obtain and disseminate science-based, actionable, quantitative information about antibiotic drug use and the development of resistance in food-producing animals and their relationship to livestock management practices. With the help of our industry and academic partners, USDA proposes to address recognized knowledge gaps and develop effective, practical mitigation strategies that will help to prolong the effectiveness of antibiotics to treat both people and animals. In fact, this action plan aligns well with the ITFAR Public Health Action Plan.

This action plan outlines USDA's current activities and proposes a comprehensive, integrated approach for future surveillance; research and development; and education, extension, and outreach activities that span three objectives (See also Figure 1):

Objective 1: Determine and/or model patterns, purposes, and impacts of antibiotic use in food-producing animals.

Objective 2: Monitor antibiotic drug susceptibilities of selected bacterial organisms in food-producing animals, production environments, and meat and poultry.

Objective 3: Identify feasible management practices, alternatives to antibiotic use, and other mitigations to reduce AMR associated with food-producing animals and their production environments.

Activity Areas

Surveillance: Ongoing voluntary monitoring of antibiotic use, AMR patterns, and management practices associated with food-producing animals and their environments at multiple points from the farm through slaughter and processing is essential. By describing the current state and evaluating changes over time, USDA can identify and respond to emerging resistance patterns or strains and objectively evaluate the effectiveness of policies and mitigation strategies that are implemented to reduce the selection of AMR. USDA possesses expertise in the design, implementation, and analysis of animal health surveillance systems, including AMR.

USDA's goal is to obtain and disseminate science-based information about antibiotic drug use, the development of resistance in food-producing animals, and their relationship to livestock management practices to develop effective, practical mitigation strategies that will help to prolong the effectiveness of antibiotics to treat both people and animals.

Research and Development: Basic and applied research is needed to better understand the ecology and mechanisms of AMR in response to antibiotic administration and use of management technologies for food-producing animals. Insufficient attention has been given to identifying management practices that reduce antibiotic use, implementing intervention strategies to reduce the development of AMR, and developing new antibiotics or alternatives to antibiotics for livestock and poultry. USDA is uniquely positioned to contribute to the body of scientific knowledge about AMR, specifically about the role of antimicrobial use in livestock, and leads the U.S. Government's research efforts in this area.

Education, Extension, and Outreach: Targeted education, extension, and outreach activities will help transfer the information USDA generates about AMR through voluntary surveillance and research to the agricultural community and the public to promote the judicious use of antimicrobial drugs in food-producing animals. Education is defined here as training delivered through formal classroom lectures and laboratory courses, while extension and outreach refer to the delivery of science-based education and training in non-formal settings to a variety of people. USDA has a long history of educating the animal agricultural community and the public.

Current Activities

USDA's current activities are foundational to efforts to address key knowledge gaps about AMR in animal production. USDA plans to continue these activities and has proposed enhancements for several. A review of the strengths and weaknesses of the current work is included in Appendix 5.

Current Surveillance:

1. National Animal Health Monitoring System (NAHMS) (APHIS, ARS, and NASS). NAHMS commodity studies involve the use of questionnaires administered to U.S. livestock, poultry, and aquaculture farmers to establish nationally representative estimates of management practices and operation/animal characteristics. NAHMS performs a study in each major commodity at 5- to 7-year intervals. With regard to AMR, NAHMS studies usually gather information about general farm policy and management practices related to reasons for use, antimicrobial class, and delivery route. All surveys are voluntary. Information is protected by Title 7, U.S. Code, Section 2276 and the Confidential Information Protection and Statistical Efficiency Act which prohibit public disclosure of individual information. In addition, personal information, including reported data, is protected from legal subpoena and Freedom of Information Act requests. In some instances, data are collected on individual animals.

NAHMS studies typically incorporate collection of on-farm biological samples. For many years, fecal samples were collected to isolate important pathogens and commensal bacteria and to determine the presence of antibiotic resistance. The repeated nature of NAHMS studies has allowed an examination of patterns over time. Finally, NAHMS studies explore actions related to preserving the health of animals on farms. These activities may reduce the need to use antibiotic drugs to prevent, control, or treat disease. Furthermore, the data allow direct evaluation of associations between management practices (including antibiotic drug use) and AMR observed in the farm setting. Such information will be important in identifying potential mitigation strategies. (Objectives 1, 2, and 3)

2. Agricultural Resource Management Survey (ARMS) (ERS, NASS, and APHIS). ARMS is an annual farm-level survey jointly administered by ERS and NASS with consultation from APHIS. All surveys are voluntary. Information is protected by Title 7, U.S. Code, Section 2276 and the Confidential Information Protection and Statistical Efficiency Act prohibit public disclosure of individual information. In addition, personal information, including reported data, is protected from legal subpoena and Freedom of Information Act requests. The survey focuses on farm finances, but includes detailed questions aimed at commercial producers of certain livestock species on production practices, including antibiotic drug use. ERS obtained data on antimicrobial use during 2004 and 2009 for hogs, and during 2006 and 2011 for broilers. These data provide estimates of antibiotic drugs used, the purpose of their use, stage of production, and type of farm. (Objectives 1 and 3)

3. FSIS sampling in slaughter plants (FSIS). Two monitoring streams are used: (1) sampling of the contents of the large intestine from a random sample of animals through the NARMS program; and (2) product sampling through Salmonella Pathogen Reduction: Hazard Analysis and Critical Control Points (PR/HACCP) verification sampling. Large intestine contents of swine (market hogs and sows), cattle (beef and dairy), and poultry (young chickens and turkeys), and product samples from young chicken, young turkey, and ground beef are being collected at slaughter establishments. Large intestine sampling, in partnership with FDA-NARMS, monitors year-to-year trends in prevalence of Salmonella and other bacteria of interest (e.g., *Campylobacter, Escherichia coli, Enterococcus*) in the gut of animals at slaughter with particular emphasis on their antibiotic susceptibility and genetic relatedness. (Objective 2)

4. The U.S. National Residue Program (NRP), administered by FSIS since 1967, is an interagency program designed to identify, rank, and test for chemical contaminants (including antibiotics) in meat, poultry, and egg products. Chemical compounds tested in the program include approved and unapproved veterinary drugs, pesticides, and environmental compounds. (Objective 1)

5. Assessment of the presence of emerging AMR organisms of public health and zoonotic potential such as methicillin-resistant *Staphylococcus aureus* (MRSA) and *Clostridium difficile*, among food-producing animals, retail products, and humans in the United States (ARS, APHIS, CDC, FDA, and universities). Several preliminary surveys have been conducted to determine the prevalence of MRSA in swine and *C. difficile* in swine, cattle, humans, and retail products. One *C. difficile* study is a collaborative project between ARS and university scientists to assess incidence in a closed population (prison system) that raises pigs and consumes the pork. Previous NAHMS studies in swine and dairy and beef cattle have also included surveillance for *C. difficile*. (Objective 2)

Figure 1:

USDA's current and proposed surveillance; research and development; and education, extension, and outreach activities by objective.

USDA will provide science-based information relating to:

<table>
<tr><th></th><th>Objective 1:
Antibiotic use in food producing animals</th><th>Objective 2:
Antibiotic drug Susceptibility in food animals and meat and poultry</th><th>Objective 3:
Mitigations to reduce AMR associated with food producing animals and their production environments</th></tr>
<tr><td rowspan="10">Surveillance</td><td colspan="3">1. National Animal Health Monitoring System (NAHMS)</td></tr>
<tr><td>2. Agricultural Resource Management Survey (ARMS)</td><td></td><td>2. Agricultural Resource Management Survey (ARMS)</td></tr>
<tr><td></td><td>3. FSIS sampling in slaughter plants (NARMS and HACCP)</td><td></td></tr>
<tr><td>4. National Residue Program (NRP)</td><td></td><td></td></tr>
<tr><td></td><td>5. Emerging AMR organisims of public health and zoonotic potential.</td><td></td></tr>
<tr><td colspan="3">1. Ongoing longitudinal studies</td></tr>
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Current

Proposed

Current Intramural and Extramural Research and Development:

6. On-farm sample collection with linkage to slaughter from swine, dairy, beef, and poultry (broiler and turkeys) (ARS). These pilot studies are evaluating potential methods for establishing a sustainable program for collecting samples from animals on farms and at slaughter for bacterial isolation and AMR testing. The project includes the collection of samples from a cohort of animals for bacterial isolation and resistance testing from farm through slaughter. These data will provide information on differences in resistance prevalence at each sampling location. Minimal antibiotic use data are being collected in this study. (Objective 2)

7. Economic effects of the use of growth-promoting antimicrobials on livestock production and costs of production (ERS and NASS). Using ARMS data, ERS assessed the impact of antibiotic use for growth promotion on output and production costs in hog finishing and broiler grow-out operations. The focused studies also assessed alternative practices in place on farms that use growth-promoting antibiotics. Current research explores the market effects on the use of certain antibiotic drugs for production purposes (i.e., growth promotion) in livestock. The research will provide estimates of the impacts on livestock production and prices, wholesale and retail meat prices and sales, and feed prices and production. (Objective 3)

8. Ongoing research on alternatives to antibiotics (ARS and NIFA). "Alternatives to antibiotics" are broadly defined as any substance that can prevent the need for or be substituted for the therapeutic use of antimicrobial drugs. ARS held an international symposium in cooperation with the World Organization for Animal Health in Paris, France, September 25–28, 2012, to highlight promising research results and novel technologies that could potentially lead to the development of alternatives to conventional antibiotics (**www.ars.usda.gov/alternativestoantibiotics/**). Numerous alternative strategies are proposed, including vaccines, prebiotics, probiotics, bacteriophages, bacteriophage gene products, bioactive phytochemicals, essential oils, naturally occurring bacterial lytic enzymes, animal-derived antimicrobial peptides, small interfering ribonucleic acids, immune enhancers, and recombinant and hyperimmune therapeutic antibodies. Through competitive and capacity funds, NIFA is supporting projects that target effective interventions, including alternatives to antibiotics, in food-producing animals. (Objective 3)

9. Intramural research to generate science-based data about mechanisms of antimicrobial resistance and strategies to reduce AMR in food-producing animals and their environments (ARS). (Objectives 1, 2, and 3)

a. Studies to better understand the mechanisms of how foodborne pathogens acquire, maintain, and transmit genes for AMR and virulence. One project investigates and characterizes plasmid maintenance, transferability, gene content, and evolution in a diverse set of *Salmonella* serotypes isolated from cattle and poultry from production to harvest environments. Understanding the diversity of plasmids and their role in a diverse set of *Salmonella* and *E. coli* (including non-O157) strains is important in establishing their role in AMR.

b. Studies to better understand the role of animal production environments in AMR. Several ongoing studies provide information on the distribution and frequency of AMR bacteria and their genes in the environment. For example, one study is determining the presence of AMR-related genes or cassettes for commonly administered agricultural antibiotics such as tetracycline, penicillin, and aminoglycosides in samples from cattle, poultry, and swine manure and manure-impacted areas. Gene transfer, both horizontal and vertical, selection via plasmid or resistance cassettes of indigenous soil bacteria, and their possible transfer into pathogens are being studied. Another project investigates the role of biofilms in the development of resistant microorganisms and transfer and persistence of resistance genes in poultry and produce. It compares the capability of Shigatoxigenic groups of *E. coli* (STEC) O157:H7 and non-O157 STEC strains and serotypes to form biofilms on food contact surfaces and the resultant bacterial dissemination.

c. Studies to better understand factors that reduce pathogens and improve animal health to reduce the use of antibiotics. ARS conducts research on actions that reduce the level of important animal and food safety pathogens for all food-producing livestock species. These studies investigate the effectiveness of new and innovative management practices to reduce pathogen load and transmission of foodborne pathogens to meat and poultry products. This includes management practices, vaccination strategies, and nutritional supplements to improve and maintain animal health as well as minimize the pathogens persisting in the animal and the environment. In addition, other important research is identifying animals that shed higher levels of foodborne pathogens and developing strategies to reduce their shedding and thus transmission of the pathogens.

10. Extramural integrated research, education, and/or extension grants that generate science-based data about antimicrobial use, mechanisms of antimicrobial resistance, and mitigations to reduce AMR in food-producing animals and their environments (NIFA). (Objectives 1, 2, and 3)

a. Since 2008, NIFA has awarded approximately $9 million in competitive awards to study AMR through programs in both its Food Production and Sustainability and Food Safety and Nutrition Institutes. Funded research has addressed how resistance develops and spreads in animals and food supply systems. The research identified critical control points and practices for mitigating the emergence, spread, and persistence of AMR in the preharvest or postharvest food environment, in products, and/or in host and environmental ecosystems.

b. NIFA has funded a project that is identifying critical on-farm control points in dairy production that will decrease antimicrobial-resistant salmonellae. In addition, grant funds through the Agriculture and Food Research Initiative (AFRI) of $2 million to $4 million are available to support systematic studies that identify intervention strategies for effective mitigation of AMR throughout the food chain.

c. In the combined 2012/2013 request for applications, the AFRI Food Safety Challenge (integrated) area made up to $2.8 million available to address effective AMR mitigation strategies. In 2013, NIFA funded two research grants to three universities and one conference for a total of $1.6 million. Specific award information can be found at **http://cris.nifa.usda.gov.**

Current Education, Extension, and Outreach:

11. Judicious use online training module for veterinarians. The National Veterinary Accreditation Program (APHIS, academic partners, FDA, and CDC) requires supplemental training every 3 years for renewal of accreditation, which allows private veterinarians to engage in regulatory work, such as writing health certificates for export or the submission of tests for diseases of regulatory importance. A module on judicious use of antimicrobials has been added to the menu of online, supplemental training modules. Such education of veterinary practitioners will support efforts to avoid both the selection of AMR and residues in animal products. The module will require periodic updates on the basis of new information gleaned from surveillance efforts and as policy related to antimicrobial drug use is implemented. For example, the FDA Guidance #213 calls for greater veterinary oversight of medically important antimicrobials used in feed or water. When the Veterinary Feed Directive is fully implemented, there will be a need to further educate veterinarians on the proper use of the directive. (Objectives 1 and 3)

12. Educational content through NIFA. NIFA provides principal Federal support for the Cooperative Extension System which serves as a national resource to disseminate validated scientific information to the private sector within every county in the United States. In recent years, the Web site **www.eXtension.org** was launched to provide even more efficient online methods to share high-quality, reliable information within and between States. Considerable Web content relating to AMR already exists within the eXtension system. Education is also part of NIFA's mission. NIFA administers curriculum development grant programs such as the Higher Education Challenge Grant program. Although formal educational development projects specifically relating to AMR have not been funded recently, these NIFA grant programs are available for institutions of higher education to apply to develop innovative teaching methods and curricula relating to specific areas of study. (Objectives 1, 2, and 3)

13. Food Animal Residue Avoidance Database (FARAD). (NIFA) This program is a resource to the food-producing industry and supports the production of safe foods of animal origin through the prevention and mitigation of violative chemical residues (i.e., drugs, antibiotics, pesticides, natural toxins, and environmental contaminants) in food animal products. FARAD (www.farad.org) is funded through NIFA and is operated by a consortium of four university laboratories (University of California–Davis, Kansas State University, University of Florida, and North Carolina State University). (Objectives 1 and 3)

Proposed Initiatives

Despite USDA's long history of activities, partnerships, and investments in AMR, considerable work remains to fill existing knowledge gaps and strengthen current, ongoing activities. This action plan proposes several initiatives that will enable USDA to use its collective expertise and strengths to develop effective, practical strategies for animal agriculture to prolong the effectiveness of antibiotics to treat people and animals. To achieve the greatest impact, these initiatives would build upon existing activities and be integrated across USDA agencies. Because all of these proposed activities are voluntary, collaborations with stakeholders and producers will be needed to leverage expertise and resources in the most efficient and effective ways

Proposed Surveillance:

1. Ongoing longitudinal studies that collect quantitative data on antimicrobial drug use and management practices along with biological samples at various points and locations from the farm and at slaughter. (Objectives 1, 2, and 3)

Description: Detailed data and biological samples could be collected from a limited number of cooperating operations that volunteer to participate over time. Initially, feedlot cattle, swine, and poultry (broilers) operations would be surveyed with dairy cattle and other commodities to follow. Questionnaires would be used to measure antimicrobial drug use (including the specific drugs, delivery system, and purpose of use) and related production practices by livestock and poultry producers. Ongoing monitoring of antimicrobial drug susceptibilities for common animal and foodborne pathogens would directly link temporal changes in these AMR patterns with on-farm antimicrobial use and other management practices. Various biological samples could also be collected at slaughter and cultured for multiple bacteria (i.e., *Salmonella*, *Campylobacter*, generic *E. coli*, and *Enterococcus*). Isolates would be tested for antimicrobial drug susceptibility. Changes in microbial and resistance status in the slaughter plant could then be evaluated in light of contemporary on-farm antimicrobial use and management practices.

Outcomes: These studies would provide quantitative data about antibiotic use, AMR patterns, and management practices on farms, their relationships, and trends over time. The ability to monitor temporal trends will be particularly useful to measure the effectiveness of policies and interventions in reducing AMR. For example, USDA could quantify changes in antimicrobial drug use on these farms after the new FDA guidelines and regulations are implemented. USDA could also produce better estimates of the quantities of antibiotics used in animal agriculture.

Ongoing monitoring of microbial and resistance status at various points in the slaughter process would help in understanding microbial flow through the system and identify points where changes in microbial load or microbial ability to adapt to the processing environment may be occurring or where interventions may be most effective to reduce microbial loads. Resulting data could be used to formulate guidelines for processors and potentially in developing new inspection strategies to prevent pathogens and other hazards from contaminating meat and poultry products. The data could inform risk analysis and provide a transparent, scientific basis for regulatory decisionmaking.

Integration: The FDA will use these data to evaluate antibiotic use by U.S. livestock and poultry producers. Producers can implement evidence-based strategies to reduce AMR that are identified through this surveillance. Finally, multiple USDA agencies and university partners will use the data to identify critical areas for further focused, collaborative research and education/outreach activities.

2. Enhanced NASS and ARMS survey questionnaires with new and expanded questions about antibiotic drug use and related production practices. (Objectives 1 and 3)

Description: Questions about antibiotic drug use will be added to existing and proposed NASS livestock surveys so that national estimates of antibiotic drug use can be determined for feedlot cattle, swine, and poultry. All surveys are voluntary. Information is protected by Title 7, U.S. Code, Section 2276 and the Confidential Information Protection and Statistical Efficiency Act which prohibit public disclosure of individual information. In addition, personal information, including reported data, is protected from legal subpoena and Freedom of Information Act requests.

Doing so will provide monitoring of trends in antimicrobial drug use over time. Similarly, new ARMS survey questionnaires with detailed coverage of antimicrobial use and related production practices will be introduced for swine and broilers. The surveys would track producer behavior before and after the finalization of the FDA Guidance #213 and the accompanying changes to the Veterinary Feed Directive rule to measure their effect, and the effect of retailer requirements pertaining to antimicrobial use on farm productivity, costs, and production practices. The survey would extend the scope of the current research that investigates the likely impact of the loss of growth-promoting drugs on outputs and production costs at the farm level and would track adoption of production practices meant to replace antimicrobial use for growth promotion.

Outcomes: These surveys will provide national data about antibiotic use and management practices on farms, their relationships, and how these change over time for three major livestock commodities. Further, data from both of these surveys would supplement ongoing surveillance conducted through NAHMS. The ability to monitor temporal trends would be particularly useful to measure the effectiveness of policies and interventions in changing antimicrobial use practices and reducing AMR. It would also better enable estimation of the quantities of antibiotics used in animal agriculture.

Integration: The results from these studies will provide the FDA with valuable information regarding the impacts of its guidance. Retailers and processors may potentially use the data to inform procurement policies that address the use of antimicrobials in livestock. Many stakeholders and the general public will be interested in more accurate estimates of antimicrobial use in livestock and poultry. The results of these surveys would be integrated with ongoing NAHMS information to further coordinate on-farm commodity studies. Finally, multiple USDA agencies and university partners will be able to use the data to identify critical areas for further focused, collaborative research and education/outreach activities.

3. Implement routine antibiotic susceptibility testing of selected animal pathogens and collate and report data across veterinary diagnostic laboratories. (Objective 2)

Description: State veterinary diagnostic laboratories test samples from clinically ill animals to identify the pathogens responsible for causing disease. AMR testing is conducted on some of these isolated pathogens. Veterinarians use this information to guide treatment for the ill animals and other animals in close contact or in the local area. However, these data on AMR patterns are rarely collated and reported at the laboratory level or across multiple laboratories. Developing a voluntary data system that links AMR testing data across State veterinary diagnostic laboratories and reports resistance trends over time for animal pathogens will help inform veterinarians' and producers' for judicious treatment decisions and promote the judicious use of antibiotics in animals.

State veterinary diagnostic laboratories routinely submit *Salmonella* isolates to the NVSL for serotyping. These isolates are typically associated with higher than expected morbidity and mortality, more severe disease, or more persistent disease conditions in groups, herds, or flocks. AMR testing is not currently performed on these isolates. However, this action plan proposes to reinitiate AMR testing on these *Salmonella* isolates. This would create a surveillance stream to identify newly emerging strains with increased resistance to multiple antimicrobial drugs or specific antimicrobial drugs of high interest (e.g., those critically important to public health). Veterinarians and producers would gain knowledge about emerging threats to animal health and information to guide treatment decisions. The public health community would benefit from a possible early warning system for potential future foodborne illness.

Outcomes: Developing this surveillance stream for monitoring AMR profiles in animal pathogens would be important to maintain animal health and encourage the judicious use of antibiotics. Specifically, this surveillance would allow veterinarians and producers to make more informed treatment decisions by using the AMR data to judge the likelihood of success of a specific antibiotic drug, to monitor the continued usefulness of a particular antibiotic, and to identify whether a new or different antimicrobial product is needed over the course of treatment. Further, it would provide information related to the unintended consequences of resistance developing in non-target pathogens if access to the production facility was granted and additional studies were initiated.

Integration: In addition to its value to the veterinary and animal agricultural communities, this newly tapped surveillance stream would provide the FDA, CDC, and public health communities with important information about AMR patterns observed in pathogens that cause disease in animals and that can potentially result in foodborne illness in people.

4. Targeted on-farm and in-plant sampling to supplement ongoing NAHMS studies and case investigations. (Objectives 1, 2, and 3)

Description: Detailed epidemiological investigations could be conducted when clusters of AMR pathogens are identified on farms as part of NAHMS, in slaughter plants through FSIS *Salmonella* HACCP verification testing, or as outbreaks of human illnesses through PulseNet. USDA would collaborate with the producers, slaughter establishments, and public health officials (as appropriate) on a voluntary basis to conduct targeted on-farm and/or in-plant biological sampling and complete questionnaires about antimicrobial use and management practices to determine the source of the pathogen and to identify mitigation strategies. Information is protected by Title 7, U.S. Code, Section 2276 and the Confidential Information Protection and Statistical Efficiency Act which prohibit public disclosure of individual information. In addition, personal information, including reported data, is protected from legal subpoena and Freedom of Information Act requests.

Outcomes: These in-depth studies would allow a more complete understanding of factors associated with specific incidents of AMR pathogens associated with food-producing animals. They could allow for a comparison of management practices on those affected operations with control (not affected) operations in an effort to identify and mitigate risk factors for the selection and spread of AMR both on farms and in slaughter plants. Additionally, they would allow for study and in-depth characterization of both target and non-target pathogens/bacteria that may or may not develop resistance when approved antibiotics are used.

Proposed Intramural and Extramural Research and Development:

5. Research on understanding the microbial ecology associated with feeding antibiotics or antimicrobials at therapeutic, preventive, and production levels. (Objectives 1, 2, and 3)

Description: Preliminary data have shown that the microbiome of the gastrointestinal system changes in response to numerous factors, including management and feeding practices, environment, transport, and the administration of antimicrobials. Expanded research is needed to better understand the causes and conditions that induce increased development of AMR in production animals. This information is critical for developing strategies to minimize the level of AMR in production animals. The programs would include a systems science approach with strong multi-disciplinary and a One Health emphasis. This research would be broad spectrum and collaborative between Federal agencies and colleges. In addition, education and outreach would be integrated into each project.

Outcomes: The results from this research would aid in understanding the role microbial ecology plays in the development of AMR. This information is critical in understanding the mechanisms and results from administration of antimicrobials and from various management strategies. Anticipated outcomes include not only new system-compatible integrated strategies for control and mitigation of AMR, but the overall holistic, judicious (risk-benefit balanced) use of antibiotics throughout the food chain from "farm to fork." An additional benefit will be support to ensure a pipeline of the next generation of scientists and educators. The resulting data will be coordinated with surveillance data to provide answers to help minimize the development of AMR and to develop alternative strategies to reduce AMR in production animals.

6. Develop innovative antimicrobials to provide alternatives to conventional antibiotics. (Objectives 1, 2, and 3)

Description: Development of specific alternatives to antibiotics, such as prebiotics and probiotics, novel antimicrobial molecules, and immune enhancement products through intramural and extramural research projects, is critically needed. Alternatives to antibiotic strategies include, but would not be limited to, the following: antimicrobial peptides; prebiotics; probiotics; bacteriophage; modulators of innate and adaptive immunity; immune modulation (including vaccines); novel approaches based on gut microbiome and host interactions; or genetic resistance to disease, including classical animal breeding. Proposals for research, education, and extension activities leading to innovative experimental methods and tools for the study of AMR and new knowledge and strategies aimed at improving animal management and husbandry methods would also be eligible for funding. This program will address AMR control in the context of the concomitant obligation to protect animal health and well-being and to support adequate (profitable) animal production efficiency.

Outcomes: There is a critical need to develop novel antibiotics and alternative strategies for preventing and treating infectious diseases not just to safeguard the use of currently available antibiotics, but also to meet the challenges of AMR. Paramount is establishing partnerships between academic and government researchers and the feed and pharmaceutical industries and their regulators to enable the development of effective and safe alternatives to antibiotics. Integrating nutrition, health, and disease research will drive new technological advances and the application of the "omic" fields. These technological advances will include new research tools and opportunities that afford scientists a hitherto unprecedented ability to discern the mechanisms by which alternatives to antibiotics can be effectively used to treat and prevent animal diseases. Working in partnership with stakeholders, funding organizations, public and private research institutions, and Federal partners will harness the resources needed to develop technologies more resilient to AMR and alternative strategies to enhance the health and welfare of animals and humans.

Proposed Education, Extension, and Outreach

7. Education and outreach for producers on judicious antimicrobial use. (Objective 2)

USDA proposes to partner with the CDC to reinitiate the "Get Smart: Know When Antibiotics Work on the Farm" (**www.cdc.gov/narms/get-smart.htm**l). USDA, in collaboration with a number of other stakeholders, proposes to reinitiate this outreach that was recently discontinued by the CDC to agricultural industries and the veterinary community.

8. Develop an online informational/educational tool to promote judicious antibiotic use in animal agriculture (**www.extension.org/search?q=antimicrobial**). (Objectives 1, 2, and 3)

The project will use the Cooperative Extension Service, including the network of local extension agents, to provide science-based information about the appropriate use of antibiotics to maximize animal health while minimizing the development of AMR. In addition to sharing new information obtained through the surveillance and research and development activities described previously, this effort will integrate concepts from existing quality assurance programs already in place in many animal agriculture industries.

9. The 2014 Food Safety Challenge area will make up to $6 million available for integrated projects that address AMR through a combination of research, education, and extension. (Objectives 1, 2, and 3)

NIFA released a request for applications on January 29, 2014. Applicants must address one or more criteria that directly include research, education, and/or extension/outreach. Specified extension and education-related criteria include the following:

Develop novel systems approaches to investigate the ecology of microbial resistance gene reservoirs in the environment (i.e., soil, water, air, storage environments), in animals, in food products, and in farm-raised aquaculture products.

a. The design of effective training, education, and outreach materials and resources (including Web-based resources) that can be easily customized to meet the unique needs of various users across the food chain from farm to fork, including, but not limited to, policymakers, producers, processors, retailers, and consumers.

b. The design and execution of studies that evaluate the impact and efficacy of proposed research, education, and extension/outreach interventions on AMR from farm to fork.

Conclusion

USDA possesses in-depth knowledge of the management practices and technologies associated with animal health, welfare, productivity, and food safety. As such, USDA is uniquely positioned to contribute to the body of scientific knowledge about AMR, specifically about the role of antimicrobial use in livestock.

This action plan is a roadmap to guide USDA's future activities to address AMR. It describes how USDA proposes to provide science-based, quantitative information about antibiotic drug use and resistance in food-producing animals and their relationship to livestock management practices. It outlines USDA's current activities and proposes a comprehensive, integrated approach for future activities that includes surveillance; research and development; and education, extension, and outreach.

The successful execution of this action plan would provide and disseminate science-based information for the veterinary and animal agricultural communities so they can implement effective mitigation strategies to prolong the effectiveness of antibiotics for use in both animals and people. Because the proposed activities are voluntary, USDA must closely cooperate with Federal, industry, commodity, and academic partners to implement this plan.

APPENDIX 1

USDA Antimicrobial Resistance Action Plan Committee

Eileen Thacker, ARS—Chair
Cyril Gay, ARS
Paula Cray, ARS
David Dargatz, APHIS
Bruce Wagner, APHIS
Eva Ring, APHIS
James MacDonald, ERS
Stacy Sneeringer, ERS
Pat Basu, FSIS
Neena Anandaraman, FSIS
Dan Kerestes, NASS
Gary Sherman, NIFA
Mervalin Morant, NIFA
Alecia Naugle, Office of the Chief Scientist

Sponsors

Steven Kappes, ARS
John Clifford, APHIS
David Goldman, FSIS

APPENDIX 2

Abbreviations and Acronyms

AALPI	Antimicrobial Alternatives for Livestock Production Research Initiative
AFRI	Agricultural Food Research Initiative
APHIS	Animal and Plant Health Inspection Service
AMR	Antimicrobial resistance
ARMS	Agricultural Resource Management Survey
ARS	Agricultural Research Service
CDC	Centers for Disease Control and Prevention
CES	Cooperative Extension System
CRIS	Current Research Information System
EEI	Element Ecology Research Initiative
EPA	Environmental Protection Agency
ERS	Economic Research Service
FARAD	Food Animal Residue Avoidance Database
FDA	Food and Drug Administration
FSIS	Food Safety and Inspection Service
ITFAR	Interagency Task Force on Antimicrobial Resistance
MRSA	Methicillin-resistant Staphylococcus aureus
NAHMS	National Animal Health Monitoring System
NARMS	National Antibiotic Resistance Monitoring System
NASS	National Agricultural Statistics Service
NIFA	National Institute of Food and Agriculture
NIFSI	National Integrated Food Safety Initiative
NIH	National Institutes of Health
NRP	National Residue Program
NVSL	National Veterinary Services Laboratories
PR/HACCP	Pathogen Reduction: Hazard Analysis and Critical Control Points
USDA	U.S. Department of Agriculture

APPENDIX 3

Timeline of Class and Antimicrobial First Marketed for Use

4 million old bacteria resistant to modern antimicrobials

Continual exposure to "natural antibiotics" from soil bacteria and fungi globally

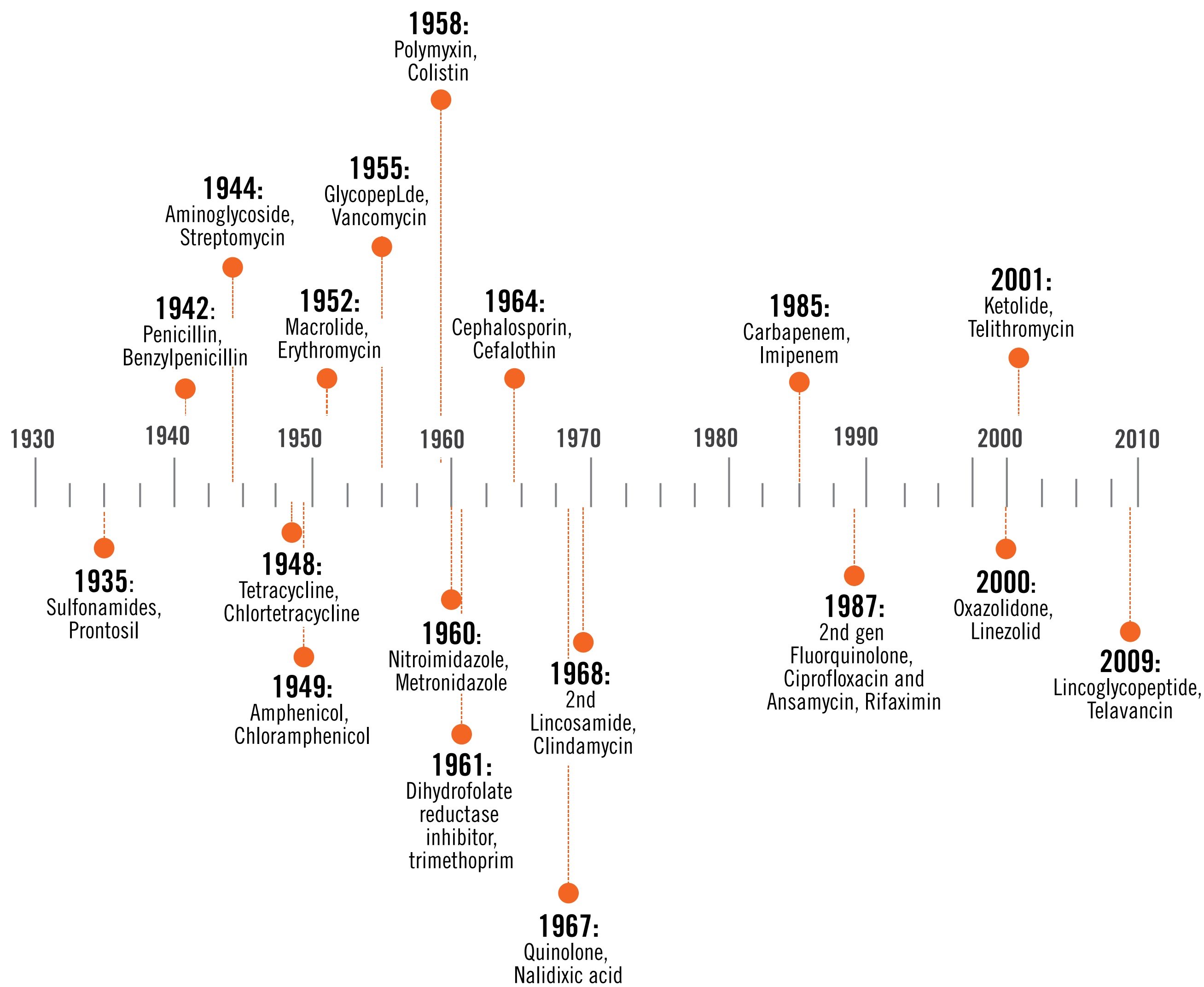


FIGURE A

Figure A depicts the timeline of antimicrobial exposure available to humans, animals, and, by default, the ecosystem/environment. The timeline starting in 1935 describes the early development and marketing of the major classes and first antimicrobial within the class. Antimicrobials were largely introduced for human use with the exception of Chlortetracycline in 1948, which was and is still used in veterinary medicine. Resistance to all classes of antimicrobials emerged in human medicine after introduction, primarily among target pathogens. Veterinary applications for some classes of antimicrobials have been approved for use against veterinary pathogens. As observed in human medicine, resistance also emerges in target pathogens. Ancillary resistance also appears in both human and veterinary non-target commensal and foodborne bacteria.

The Collective Antimicrobial Resistance Ecosystem

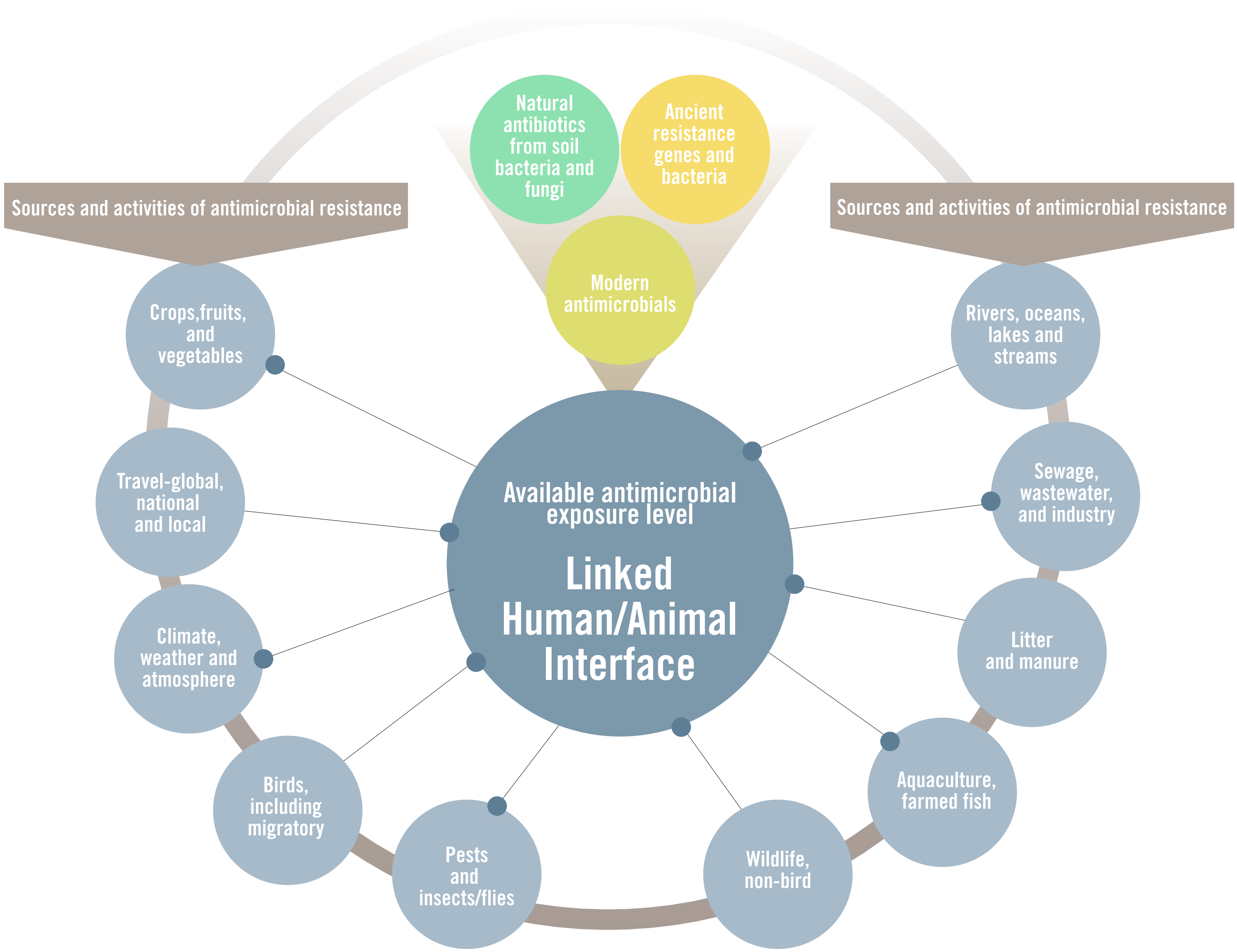


FIGURE B

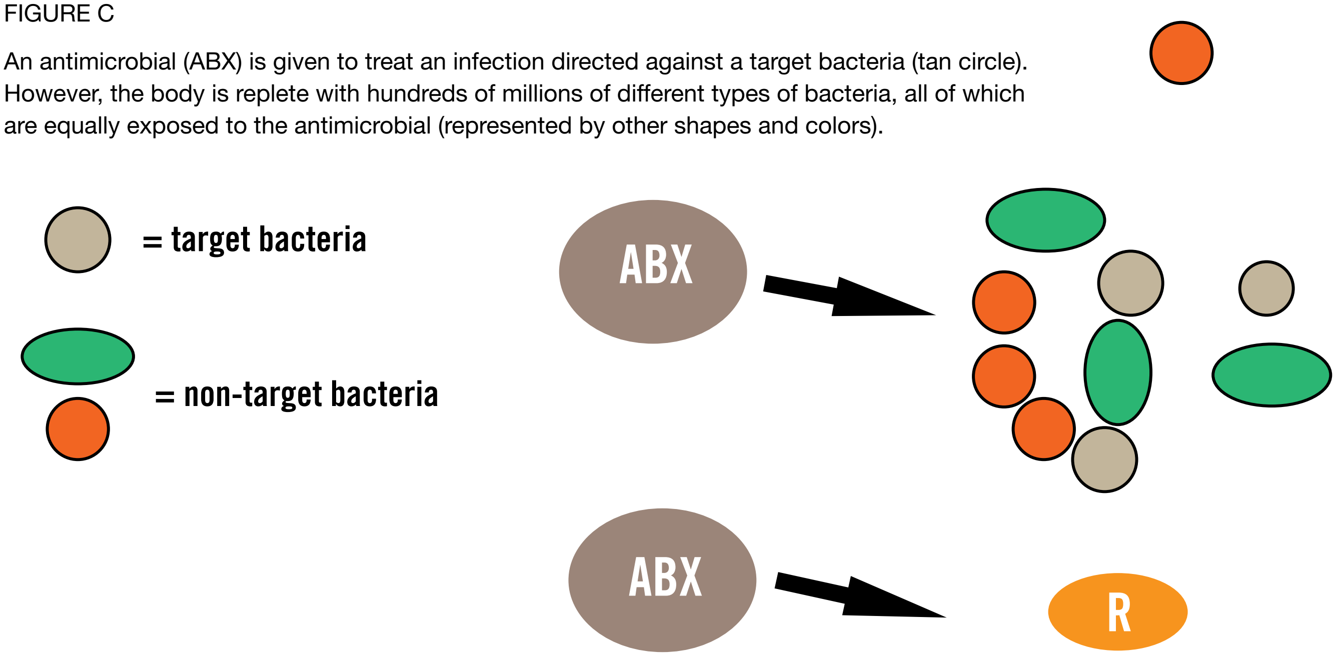
As described in figure A, the available antimicrobial exposure will affect the bacterial populations humans and animals are exposed to both in the absence and presence of antimicrobial use within the veterinary and medical disciplines.

Unlike previous depictions, which typically show a circular continuum with uni- and bi-directional flows of resistant bacteria impacting certain outcomes and in particular humans and animals, this diagram links humans and animals under the One Health concept as both are impacted by the available antimicrobial exposure levels as well as the contribution(s) to the resistance issue afforded by each surrounding circle. Contributions may consist of direct sources of resistant bacteria or resistance genes or indirect sources via vectors that serve to move resistant bacteria or deposit feces containing resistant bacteria in distant places. The curved line interconnects each circle as no one source/activity within a circle is independent of the other.

Collectively the human/animal/available antimicrobial exposure level/circular sources and activities of antimicrobial resistance comprise the global ecosystem that continues to add and delete antimicrobial resistance attributes over time.

FIGURE C

An antimicrobial (ABX) is given to treat an infection directed against a target bacteria (tan circle). However, the body is replete with hundreds of millions of different types of bacteria, all of which are equally exposed to the antimicrobial (represented by other shapes and colors).



Non-targeted bacteria (green) which either harbored or acquired resistance gene(s) were able to divide to numbers that potentially either harms the host, are excreted at levels to other susceptible hosts, or are transferred by food, vectors or other means to other hosts resulting in illness.

Resistance profile	Strain 1 JGP01.0003 (n=1216)	Strain 2 JGPX01.0001 (n=365)	Strain 3 JGPX01.0342 (n=324)	Strain 4 JGPX01.0041 (n=153)
No Resistance	0.8%	92.9%	76.5%	87.0%
Streptomycin/Tetracycline	54.1%	0.3%	3.9%	1.0%
Tetracycline	25.2%	0.6%	0.7%	1.0%
Amoxicillin-clavulanic acid/Ampicillin/Cefoxitin/ Cetiofur/Ceftriaxone/Streptomycin/Tetracycline	10.3%	0.0%	2.0%	1.0%
Amoxicillin-clavulanic acid/Ampicillin/Cefoitin/ Cetiofur/Ceftriaxone/Tetracycline	4.5%	0.3%	0.0%	0.0%
Amoxicillin-clavulanic acid/Ampicillin/Cefoxitin/ Cetiofur/Ceftriaxone/Tetracycline	0.0%	0.0%	6.2%	4.0%
Gentamicin/Streptomycin/Sulfamethoxazole/ Tetracycline	1.7%	0.0%	0.0%	1.0%
Gentamicin/Sulfamethoxazole	0.0%	0.0%	0.0%	0.0%
Gentamicin/Sulfamethoxazole	0.0%	0.0%	5.6%	0.0%
Amoxicillin-clavulanic acid/Ampicillin/Cefoxitin/ Ceftiofu/Cerftriaxone/Chloramphenicol/Gentamicin/ Kanamycin/Streptomycin/Sulfamethoxazole/ Tetracycline	0.0%	4.0%	0.0%	1.0%
Amoxicillina-clavulanic acid/Ampicillin/Ceftiofur/ Ceftriaxone/Tetracycline	0.8%	0.0%	0.7%	0.0%

Figure D

Figure D shows the differences in antimicrobial resistance patterns between four strains of *Salmonella* Kentucky.

This figure illustrates these differences. Among the group or serotype Kentucky for *Salmonella*, four different strains have been identified by a molecular technique called pulsed field gel electrophoresis. These four strains behave very differently. A majority, but not all, of the strains are susceptible to all antimicrobials tested. For strain 1, less than 1 percent are susceptible to all antimicrobials tested, while 54 percent are resistant to Streptomycin and Tetracycline, two of the earliest antibiotics developed for use in human and veterinary medicine. Other differences in resistance are noted.

APPENDIX 4

USDA Agencies' Roles in Antimicrobial Resistance Mitigation Efforts

The Agricultural Research Service (ARS) is the USDA's intramural research program. ARS research considers AMR from perspectives of animal health, food safety, and public health. Areas of research include: investigating changes in the gut microbiome in response to antibiotics; investigating mechanisms of the development of AMR; identifying and characterizing resistant bacteria; developing alternatives to antibiotics; understanding the effects of antibiotic administration on manure and the environment; and exploring the potential for transfer of antimicrobial-resistant foodborne pathogens or resistance genes from food animals (or their environment) through food processing to consumers.

The Animal and Plant Health Inspection Service (APHIS) conducts monitoring and surveillance activities to characterize health and management of livestock and poultry populations on farms. As a component of those activities, APHIS characterizes on-farm use of antibiotic drugs. APHIS collects samples on farms to determine the prevalence of select zoonotic pathogens and includes characterizing resistance to antimicrobial drugs. APHIS evaluates relationships between management practices, use of animal health practices, and on-farm antimicrobial use and resistance. The National Veterinary Services Laboratories of APHIS is a reference laboratory for animal pathogens and helps accurately identify and characterize pathogens of animals in support of veterinary diagnostic laboratories and the academic community to identify new antibiotic drug resistance mechanisms and AMR testing.

The Economic Research Service (ERS) analyzes the effects of production inputs and practices, including antibiotic drugs on production, costs, and revenues on farms. In addition, ERS evaluates the effects of changes in farm-level productivity, costs, and prices on domestic and international markets for agricultural commodities and food products. As part of that effort, ERS maintains extensive databases on the farm sector economy, including the agricultural and food markets.

The Food Safety and Inspection Service (FSIS) is responsible for ensuring that the Nation's commercial supply of meat, poultry, and egg products is safe, wholesome, and correctly labeled and packaged, as required by the Federal Meat Inspection Act, the Poultry Products Inspection Act, and the Egg Products Inspection Act. FSIS monitors antimicrobial use and AMR at slaughter and verifies that establishments have food safety systems in place to minimize the level of pathogens that reach consumers.

The mission of the National Agricultural Statistics Service (NASS) is to provide timely, accurate, and useful statistics in service to U.S. agriculture. NASS conducts surveys and prepares reports covering virtually every aspect of U.S. agriculture. In partnership with APHIS and ERS, NASS carries out surveys and collects information on antimicrobial use practices using statistically drawn samples from a maintained list of farmers and ranchers in the United States.

The National Institute of Food and Agriculture (NIFA) is USDA's primary extramural research, education, and extension funding agency. NIFA leads food and agricultural sciences by supporting **research, education**, and **extension** programs in the Land-Grant University System and other partner organizations. In recent years, proposals funded through NIFA's Food Production and Sustainability or Food Safety and Nutrition institutes have addressed how resistance develops and spreads in animals and food supply systems and the development of alternatives to antibiotics. NIFA's Small Business Innovation Research program supports innovation and product development in many areas, including vaccine development and alternatives to antibiotic use.

APPENDIX 5

Strengths and Weaknesses of Current Objective Projects

Current Objective 1 Projects:

Strengths

- Projects capture nationally representative samples for target populations and provide some basic information about drug use and current practices with differing levels of specificity (e.g., qualitative vs. quantitative, animal level vs. farm level).
- Current NAHMS surveys contain detailed information on general antibiotic administration practices that encompass number of animals treated, purpose of treatment, and delivery method.
- ARMS links estimates of antibiotic usage by stage of production and reason for use with farm production attributes (e.g., farm size, contractual relationships, age of facilities) and farm financial variables.
- NRP measures drug residues in all animal species to verify that approved drugs are used according to FDA regulations.

Weaknesses

- NAHMS and ARMS identify whether antibiotics are used and for what purpose, but they do not estimate quantities used.
- NAHMS surveys are conducted periodically (generally, every 5–7 years), leading to a series of point-in-time estimates rather than providing any ongoing real-time surveillance of AMR or antimicrobial use during the interim periods.
- The surveys do not track the same farms over time, making it difficult to identify causal factors associated with patterns of drug use or resistance.
- Lack of integration of ARMS data and coordination between APHIS, ERS, and NASS.
- With reduced ARMS funding, antimicrobial drug use questions will be eliminated in future livestock versions of the survey.
- NRP tests a limited number of animals and may not detect the lower levels of antimicrobials typically used for growth promotion. It is only a proxy for information about antimicrobial drug use.
- FARAD data are retrospective only.

Current Objective 2 Projects:

Strengths

- Pilot on-farm sampling will provide information on potential study methods for monitoring the AMR profile of organisms present in animals and how consistent a bacterial population is with samples collected at the site where those animals are slaughtered. The collaboration between Federal agencies and university scientists constitutes a valuable consortium of expertise for assessing AMR and future research methods.
- NAHMS studies of bacterial isolates are broadly representative of what is observed across the industry. Standard methods are used across multiple commodities, which facilitate a consistent measure of prevalence of resistance and associations with animal and management factors. NASS ensures the confidentiality of data collected by NAHMS.
- The current evaluation of clinical Salmonella isolates by the National Veterinary Services Laboratories (NVSL) of APHIS provides a picture of the populations of Salmonella serotypes in sick animals.
- Large intestine and cecal content sampling in slaughter plants by FSIS has the potential to provide ongoing information on trends in prevalence of resistance among bacterial flora in animals at slaughter. PR/HACCP sampling is also providing data on salmonellae in products meant for consumers. The PR/HACCP selection of samples is risk-based, so more samples are collected at establishments with a questionable history of process control, thus potentially increasing the recovery of salmonellae.
- Identification of the impact of AMR bacteria in manure and associated with biofilms is important in determining the ecological and environmental impacts of the administration of antimicrobials.
- Surveillance data are used by scientists applying for NIFA grants to guide hypothesis development and to target study focus and design. It is anticipated that data generated by NIFA scientists will in turn complement and inform ongoing official surveillance efforts.

Weaknesses

- The on-farm/slaughter project is a pilot project with a small sample size, and although it provides important preliminary information on methods, it will need to be repeated and/or expanded.
- The samples collected in current NAHMS studies are concentrated on enteric pathogens of importance to public health, excludes animal pathogens, and are periodic (every 5–7 years per species). Sample numbers are limited due to laboratory costs and capacity, which precludes precise national estimates of resistance prevalence.
- Interpretation of the data on clinical Salmonella isolates from NVSL is hampered by the limited data on sources and circumstances that accompany the isolates.
- The number of large intestine content samples collected by FSIS at slaughter is small, so it may be difficult to detect enough salmonellae to determine true prevalence that might be reflective of year-to-year trends. Animals are not identified, so it is not possible to trace samples back to management practices on the farm such as antibiotic drug use. Furthermore, large intestine contents could reflect microbial status on the farm, at transport, or at holding, so it is difficult to infer results from a specific sampling location. PR/HACCP sampling is currently risk-based and not random, so it cannot be used to determine year-to-year trends in national prevalence. Furthermore, the PR/HACCP program tests only for levels of Salmonella. Neither the large intestine content sampling nor PR/HACCP programs collect information on management practices that may affect changes in microbial profiles, such as the use of in-plant antimicrobial interventions.
- Coordination might be improved between NIFA's process of developing requests for applications, NIFA grantees, and official surveillance data collection to expand and enhance the scope, value, and impact of NIFA-supported AMR-related science.
- NIFA cannot formally request information generated through the conduct of any funded projects beyond the required Final Termination Report of the study. Therefore, important follow-on data analyses, resulting scientific advances, outcomes, and impacts are not captured in the CRIS database.

Current Objective 3 Projects:

Strengths

- Large nationally representative samples are available for NAHMS and ARMS.
- ARMS contains reliable estimates on annual outputs, inputs, and costs for economic analyses.
- Research projects assessing alternatives to antibiotics are being implemented and new products are in the research pipeline.
- Alternatives to antibiotics with defined mechanisms of action provide new opportunities for the selection of multiple products that can work synergistically.
- Alternatives to antibiotics that affect the gut microbiome, such as phytochemicals and immune enhancers, provide new opportunities for integrating nutrition, health, and disease research.
- Many opportunities exist to seek funding from sources that have an interest in both agriculture and public health.
- Partnering can occur between the private sector and stakeholders to seek funding and support.
- NAHMS studies concurrently evaluate AMR, drug use, and other management practices on farms.
- Collaboration and partnerships (e.g., between USDA and FDA) ensures that issues of common interest are being addressed across agencies and departments, where appropriate.
- Integration of research, education, and extension efforts by NIFA ensures that topics are relevant to stakeholders and that subsequent dissemination, communication, and application of science-based data and knowledge occurs to various end users.

Weaknesses

- NAHMS studies are periodic and cross-sectional, which limits their timeliness and the ability to make causal inferences.
- ARMS estimates are based on nonexperimental data (i.e., they compare outcomes for users and nonusers). Because users and nonusers may differ in several ways, it is more difficult to identify causality, even with the use of statistical matching techniques.
- ARMS identifies only whether antimicrobial drugs are used (there are no quantity measures), and includes only two animal species—broilers and swine.
- Lack of clear regulatory pathways for licensing and marketing alternatives to antibiotics, including whether new molecules will be regulated as a drug, biologic, feed additive, or possibly all three.
- Lack of national and international standards to meet requirements of efficacy, safety, and quality of alternatives to antibiotics.
- Research on finding alternatives to antibiotics are poorly funded with a poor success rate in successfully obtaining extramural funding.
- Identifying alternatives to antibiotics that can be used for both disease treatment and growth promotion has a low success rate.
- By necessity, NIFA's funding programs that include AMR are limited not only by financial constraints, but also the parameters/priorities identified by NIFA on the basis of stakeholder input. Only the most outstanding projects are selected for funding, and they may be focused on program priority topics other than or in addition to those addressing Objective 3.

June 2014