



FARM FOUNDATION® FORUM

ANTIMICROBIAL STEWARDSHIP IN
AGRICULTURE: HOW FAR HAVE WE COME
AND WHAT'S NEXT?

SEPTEMBER 27, 2022



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MARTHA KING

Vice President, Programs and Projects
Farm Foundation

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PEOPLE AND IDEAS
into
ACTION.



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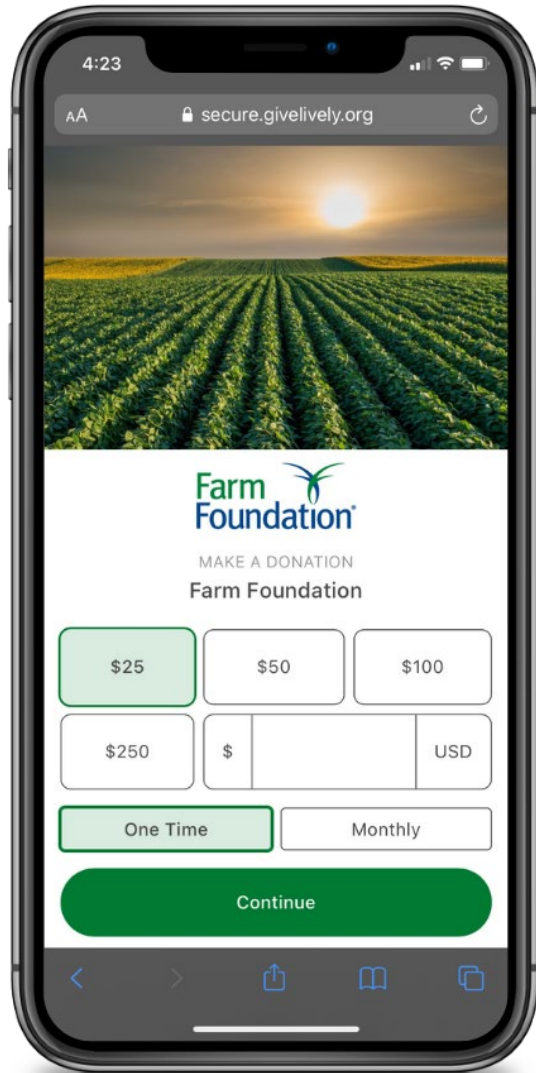
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VISION:

To **build** a future for farmers, our communities, and our world.

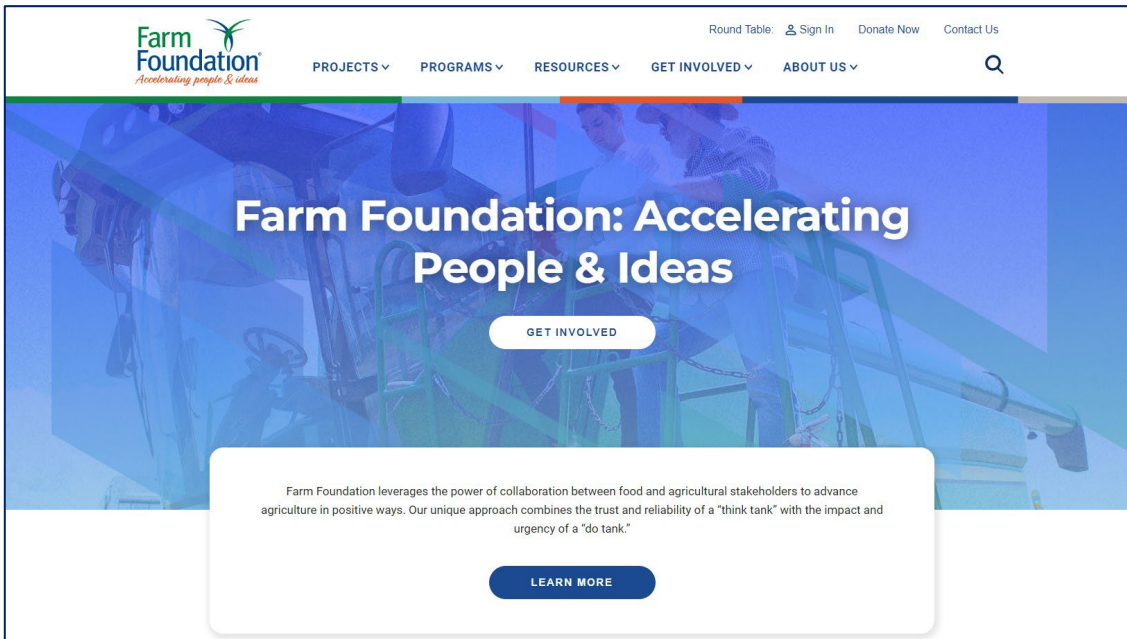
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IMPORTANT NOTES

- Submit questions by clicking on the **Q&A Button** at the bottom of your screen.
- Please **include your name and company** so questions may be contextually understood.
- Due to **time limits**, we may not be able to ask all questions submitted.
- This Forum is being recorded and will be posted on our website at **farmfoundation.org** as well as the Farm Foundation **YouTube** channel.
- Please take the **short survey** at the conclusion of the Forum.



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DR. PAUL PLUMMER

Moderator

Director, National Institute of Antimicrobial Resistance Research and Education

Associate Dean of Research and Graduate Studies, College of Veterinary Medicine, Iowa State University



NIAMRRE

Coordinating action to combat the global threat of antimicrobial resistance.



ONE HEALTH APPROACH

HUMANS + ANIMALS + ENVIRONMENT

VISION

NIAMRRE will be the trusted leader in coordinating One Health efforts that preserve the ability to prevent and treat infectious diseases for generations to come.

MISSION

NIAMRRE drives cross-sector engagement and coordinated action to combat the global threat of Antimicrobial Resistance across humans, animals, and the environment.

Current NIAMRRE Members



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DR. WILLIAM FLYNN

Deputy Director for Science Policy,
Center for Veterinary Medicine,
U.S. Food and Drug Administration

Updates on AMR Activities

FDA, Center for Veterinary Medicine

Farm Foundation Forum: Antimicrobial Stewardship in Agriculture
September 27, 2022

William T. Flynn, DVM, MS
Deputy Director for Science Policy
FDA Center for Veterinary Medicine

Supporting Antimicrobial Stewardship in Animals

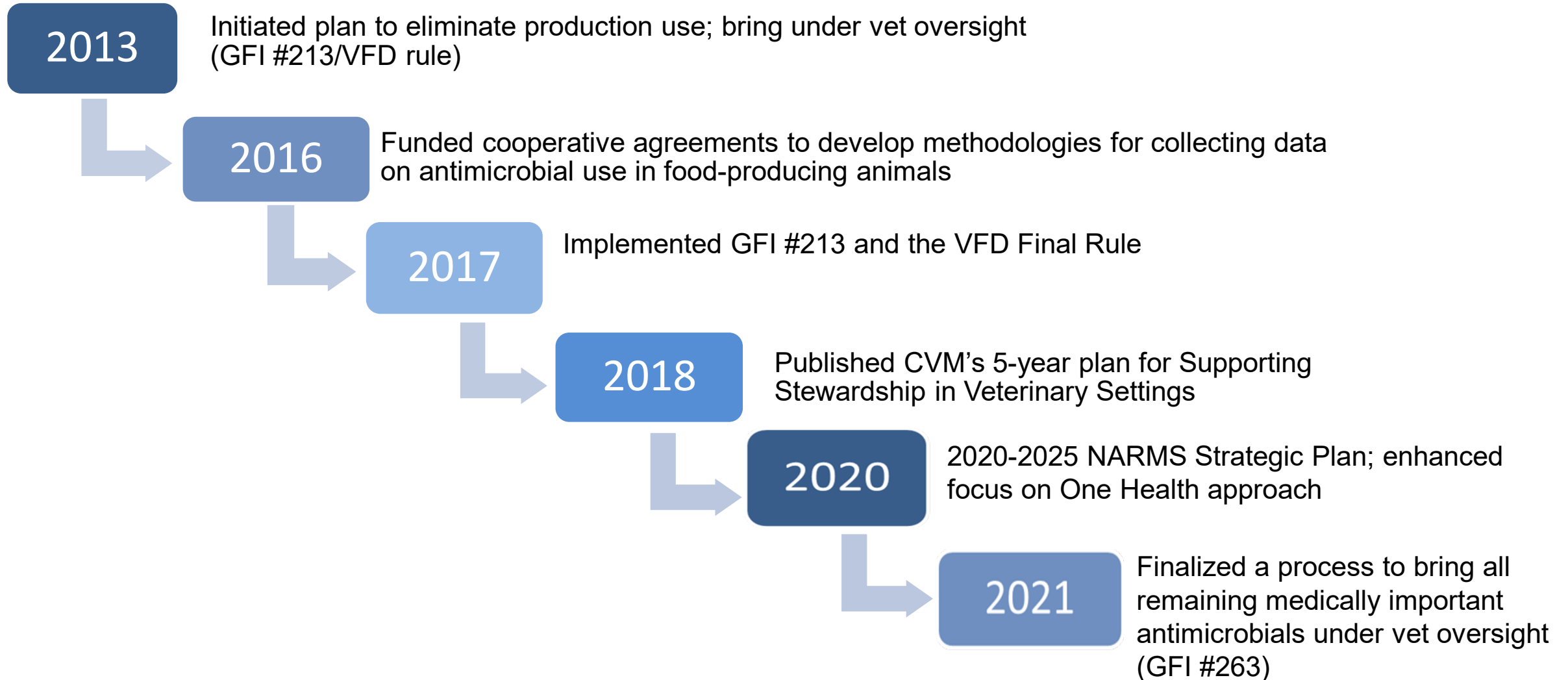
FDA/CVM's Key Areas of Focus (Goals of CVM's 5-year stewardship plan)

- Evaluating use conditions of approved animal antimicrobial products
- Promoting antimicrobial stewardship at the user level
- Collecting data to monitor antimicrobial use and antimicrobial resistance in animals

CVM's Approach for Implementing Change

- Focusing actions or mitigations on drugs of greatest concern: drugs that are important human therapies (“medically important antimicrobials”)
- Emphasizing collaboration and seeking cooperation from industry to take action voluntarily

Important Milestones



Supporting Antimicrobial Stewardship

Concept Paper: Potential Approach for Ranking of Antimicrobial Drugs According to Their Importance in Human Medicine: A Risk Management Tool for Antimicrobial New Animal Drugs

Introduction

This concept paper discusses a potential approach to considering the human medical importance of antimicrobial drugs when assessing and managing antimicrobial resistance risks associated with the use of antimicrobial drugs in animals. In 2003, FDA established a list ranking antimicrobial drugs according to their relative importance in human medicine primarily for the purpose of supporting a qualitative risk assessment process outlined in agency guidance. It was envisioned by the Agency at the time the current medical importance rankings list was published that it would periodically reassess the rankings to align with contemporary science and current human clinical practices. To that end, this paper describes a potential revised process for ranking antimicrobial drugs according to their relative importance in human medicine, potential revised criteria to determine the medical importance rankings, and the list of antimicrobial drug medical importance rankings that would result if those criteria were to be used.

Disclaimer: This concept paper is for discussion purposes only. The intent of this concept paper is to obtain public comment and early input on a potential approach to consider the human medical importance of antimicrobial drugs when assessing and managing antimicrobial resistance risks associated with the use of antimicrobial drugs in animals. This concept paper does not contain recommendations and does not constitute draft or final guidance by the Food and Drug Administration. It should not be used for any purpose other than to facilitate public comment. FDA intends to consider all comments received on this concept paper before issuing draft guidance for additional comment.

Background

Antimicrobial drugs¹ have been widely used in human and veterinary medicine for decades, with benefits to both human and animal health. The development of resistance to this important class of drugs, and the resulting loss of their effectiveness as antimicrobial therapies, poses a serious human and animal health threat. Misuse and overuse of antimicrobial drugs creates unnecessary selective evolutionary pressure that can enable antimicrobial-resistant bacteria to predominate over antimicrobial-susceptible bacteria, thus increasing opportunities for individuals to become infected by resistant bacteria and limiting

¹ The term "antimicrobial" refers broadly to drugs with activity against a variety of microorganisms including bacteria, viruses, fungi, and parasites. Antimicrobial drugs that have specific activity against bacteria are referred to as antibacterial or antibiotic drugs. The broader term "antimicrobial," is used

Assessing AMR risks for new products

- **Guidance #152** - finalized in 2003, outlines a risk assessment (RA) approach for evaluating AMR risks as part of new animal drug approval process.
- One input to this RA process is the human medical importance of drug in question
 - In **Oct 2020** CVM issued a concept paper outlining a potential approach for updating the current list of antimicrobial drugs ranked by their importance in human medicine (commonly referred to as "Appendix A" GFI #152)

Supporting Antimicrobial Stewardship

Veterinary oversight

Guidance #263 - published June 2021, outlines a 2-year plan for drug sponsors to voluntarily transition to veterinary oversight all medically important antimicrobials that are still available OTC

- Target for completion June 2023
- Approx. 90 approved drug applications impacted
- Ongoing outreach efforts being targeted to most impacted animal production sectors
- When complete, all medically important antimicrobials will be under the oversight of veterinarians.

#263

**Recommendations for Sponsors of
Medically Important Antimicrobial
Drugs Approved for Use in Animals to
Voluntarily Bring Under Veterinary
Oversight All Products That Continue to
be Available Over-the-Counter**

Guidance for Industry

For further information regarding this document, contact AskCVM@fda.hhs.gov.

Additional copies of this guidance document may be requested from the Policy and Regulations Staff (HFV-6), Center for Veterinary Medicine, Food and Drug Administration, 7500 Standish Place, Rockville MD 20855, and may be viewed on the Internet at either <https://www.fda.gov/animal-veterinary> or <https://www.regulations.gov>.

U.S. Department of Health and Human Services
Food and Drug Administration
Center for Veterinary Medicine (CVM)

June 2021

Supporting Antimicrobial Stewardship

Potential Approach for Defining Durations of Use for Medically Important Antimicrobial Drugs Intended for Use In or On Feed: A Concept Paper

I. Introduction

This concept paper is focused on approved new animal drug applications (NADAs) and abbreviated new animal drug applications (ANADAs) containing antimicrobial drugs important to human medicine ("medically important antimicrobial drugs" as discussed further in section [III. Scope](#) below) for use in or on the medicated feed of food-producing animals that are currently approved with one or more indications that have an undefined duration of use. The purpose of this concept paper is to obtain early input from the public on a potential framework for how sponsors could voluntarily change the approved conditions of use to establish appropriately defined durations of use for such products where none currently exist. The potential framework outlined in this concept paper, if it were later to be adopted through guidance, would help to ensure all medically important antimicrobial new animal drugs are administered in alignment with the principles of judicious use.¹ Establishing appropriately targeted durations of use to mitigate the development of antimicrobial resistance would be consistent with previous efforts by FDA to protect public health by promoting the judicious use of medically important antimicrobial drugs in animals.

Disclaimer: This concept paper is for discussion purposes only. The intent of this concept paper is to obtain public comment and early input on a potential framework for how sponsors could voluntarily change the approved conditions of use for medically important antimicrobial drugs used in or on the medicated feed of food-producing animals to establish appropriately defined durations of use where none currently exist. This concept paper does not contain recommendations and does not constitute draft or final guidance by the Food and Drug Administration. It should not be used for any purpose other than to facilitate public comment. FDA intends to consider all comments received on this concept paper before issuing draft guidance for additional comment.

II. Background

On April 13, 2012, FDA issued Guidance for Industry (GFI) #209, "The Judicious Use of Medically Important Antimicrobial Drugs in Food-Producing Animals."² In GFI #209, FDA stated that the

¹ Please see FDA CVM Webpage, "Judicious Use of Antimicrobials," <https://www.fda.gov/animal-veterinary/antimicrobial-resistance/judicious-use-antimicrobials>. (Content current as of 4/30/2020)

² <https://www.fda.gov/media/79140/download>

Defining duration of use

- **Concept paper** - In Jan 2021 CVM published concept paper outlining potential framework for how drug sponsors could voluntarily establish defined durations of use for those medically important antimicrobials that currently lack a defined duration of use.
 - affects certain approved feed-use medically important antimicrobial products
 - objective is to optimize use (to better define when and for how long to administer) so that effectiveness is maintained, but extent of exposure is minimized
 - Comment period closed June 2021; over 31,000 received
 - Next steps include developing and seeking input on draft guidance

Assessing the Impact of AMR Activities

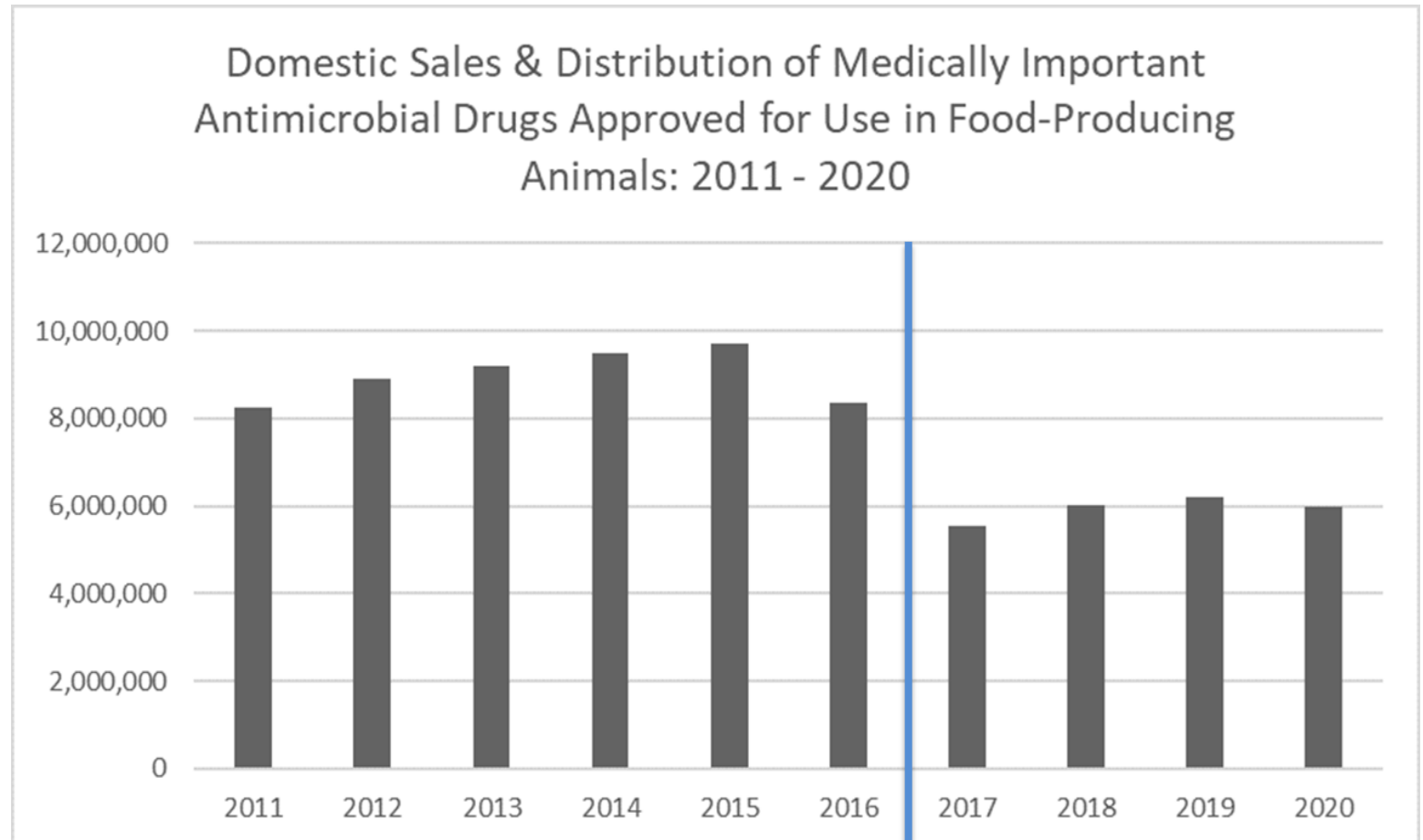
- Need for data and appropriate metrics to assess impacts of actions taken and monitor progress of stewardship initiatives
- Ongoing work to enhance collection of data on –
 - antimicrobial resistance
 - volume of antimicrobial drug sales/distribution
 - volume of antimicrobial drug use in animals



Changes in Sale and Distribution Data

The 2020 Sales and Distribution report show:

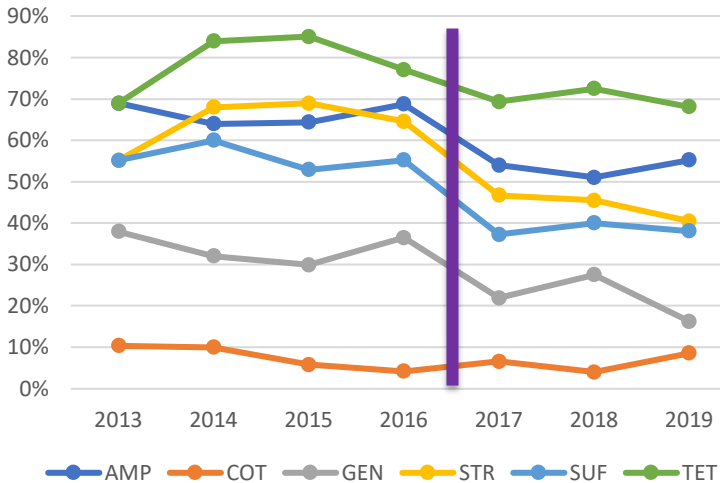
- Domestic sales decreased by three percent between 2019 and 2020.
- Decreased 33% between years 2016 and 2017
- That is a 38% decrease since 2015, which was the peak year of sales



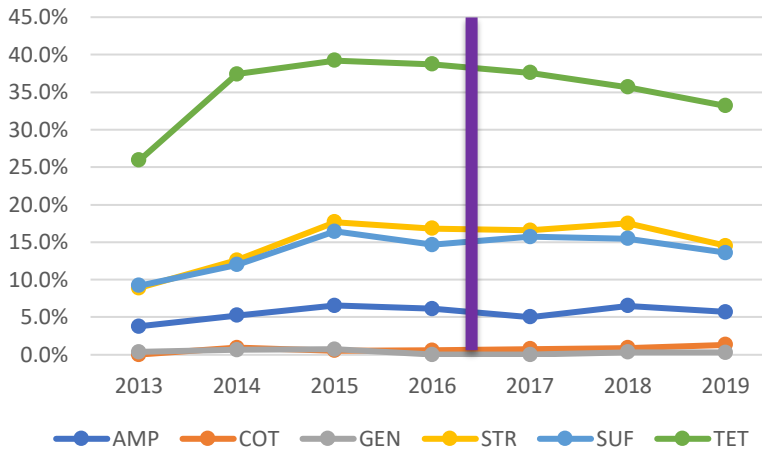
AMR Trends from the 2019 NARMS Report

Data sources for 2019 NARMS
Integrated Summary

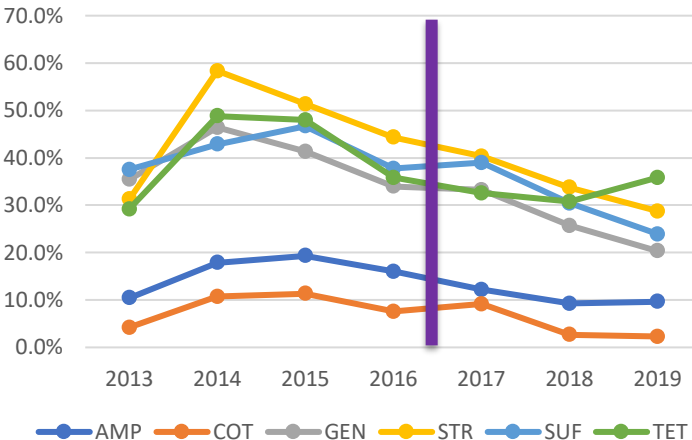
Turkey Cecal E. coli



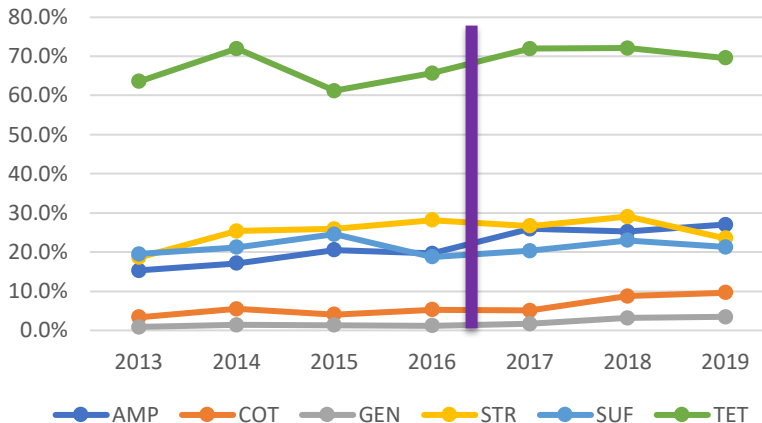
Beef Cecal E. coli



Cecal Chicken E. coli



Swine E. coli



Data Collection: Antimicrobial Use (AMU)

FDA Cooperative Agreements

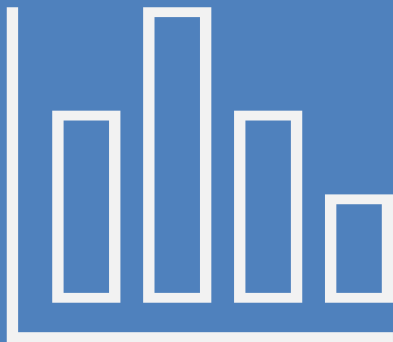
FDA issued a two Funding Opportunity Announcements

- March 2016 - focused on 4 major food-producing species (cattle, swine, turkeys, chickens)
- Feb 2020 - focused on dogs and cats

Requested proposals that would:

- Provide detailed data that reflect actual use
- Pilot methodologies for collecting, summarizing, and reporting AMU data
- Foster public-private partnerships/ collaboration
- Leverage existing data systems and minimize burden to collect data
- Incorporate strategies for protecting confidential information

Challenge: Need for Better Data and Metrics



- Sales data limitations
- Need data that better reflect actual use
- Lack of existing infrastructure

Exploring strategies for collection of antimicrobial use data

- Initiated project with Reagan-Udall Foundation for FDA
- Exploring feasibility of public private partnership model
- Benefits include:
 - Enable monitoring of trends; help understand AMR drivers
 - Foster antimicrobial stewardship
 - Inform regulatory and policy decision making
 - Enhance transparency regarding antimicrobial use

What's Next for CVM?

Advance ongoing initiatives in 5-year (2019-2023) AMR plan

- Transition OTC products to Rx (June 2023)
- Update process for ranking importance for human medicine
- Better define duration of use for certain feed use products
- Consider needed measures in companion animal sector
- Building an approach for collecting antimicrobial use information from animals

Have initiated new strategic planning process

- Examining need for additional actions as current AMR plan ends in September 2023





IMPORTANT CHANGES HAVE
BEEN MADE REGARDING
ANTIMICROBIAL USE



FOCUS ON ANTIMICROBIAL
STEWARDSHIP AND OPTIMIZING
THE USE OF ANTIMICROBIALS IN
VETERINARY SECTOR



EMPHASIS ON STAKEHOLDER
ENGAGEMENT IN DEVELOPING
COLLABORATIVE STRATEGIES
FOR IMPLEMENTING CHANGE

In Conclusion







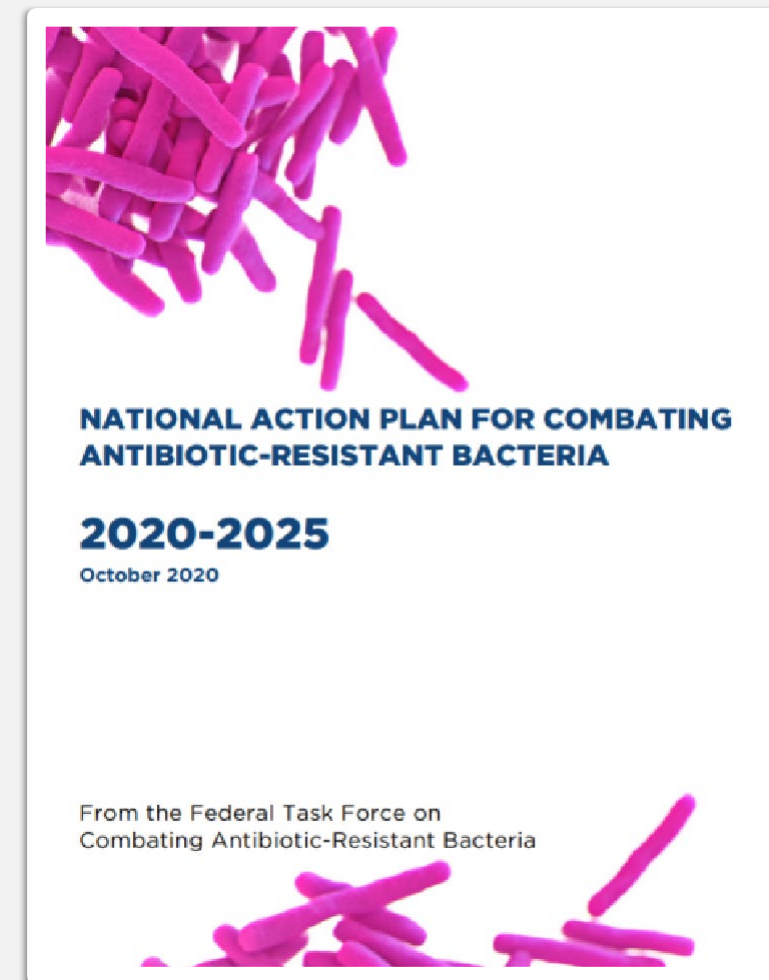
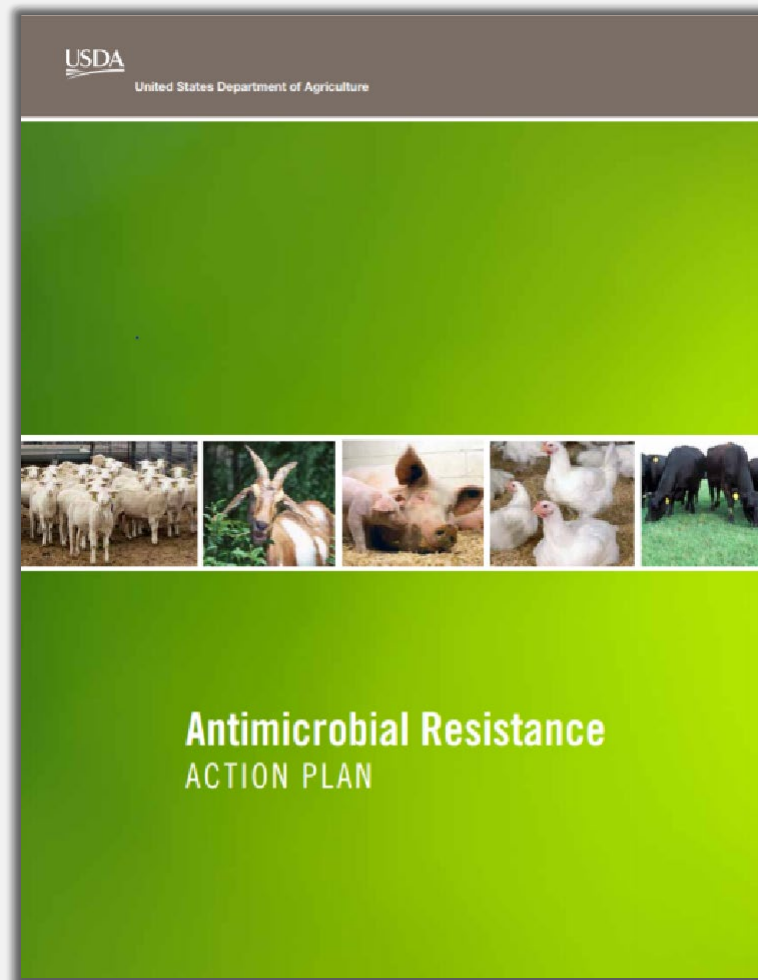
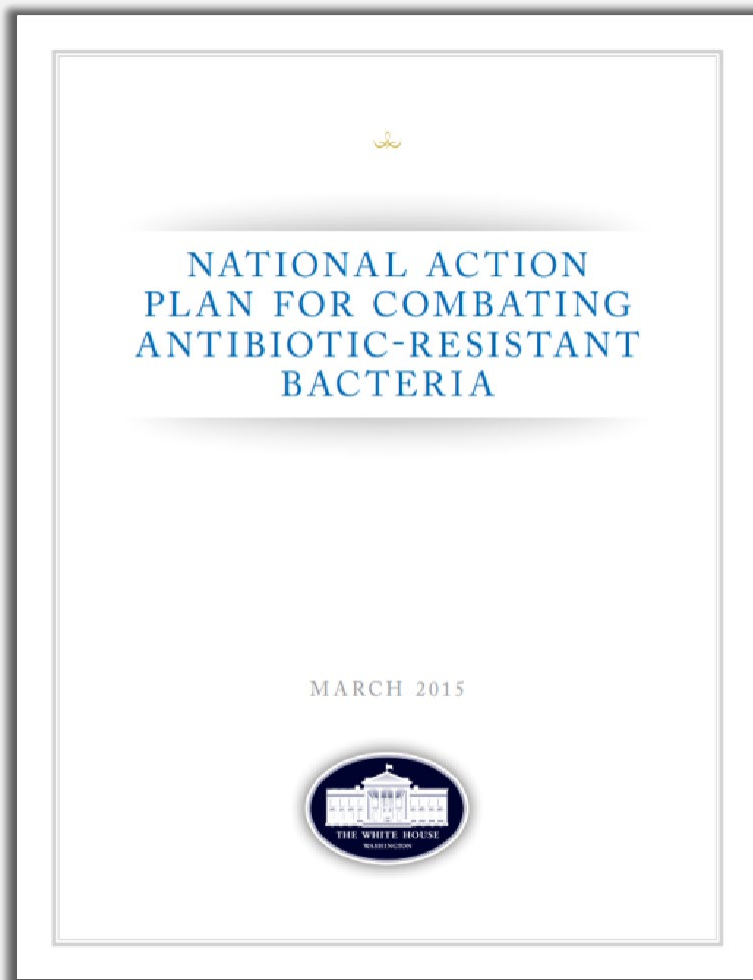
DR. CHELSEY SHIVLEY

Antimicrobial Resistance Coordinator,
Office of Interagency Coordination for USDA
APHIS Veterinary Services

Antimicrobial Stewardship in Agriculture: USDA APHIS Perspective



Chelsey Shivley, DVM, PhD, DACAW
Veterinary Epidemiologist
Farm Foundation Forum
September 27, 2022



Veterinary Services AMR Activities

**U.S. Department of
Agriculture**



Antimicrobial Use &
Stewardship Monitoring



Antimicrobial Resistance
Monitoring



Education & Outreach



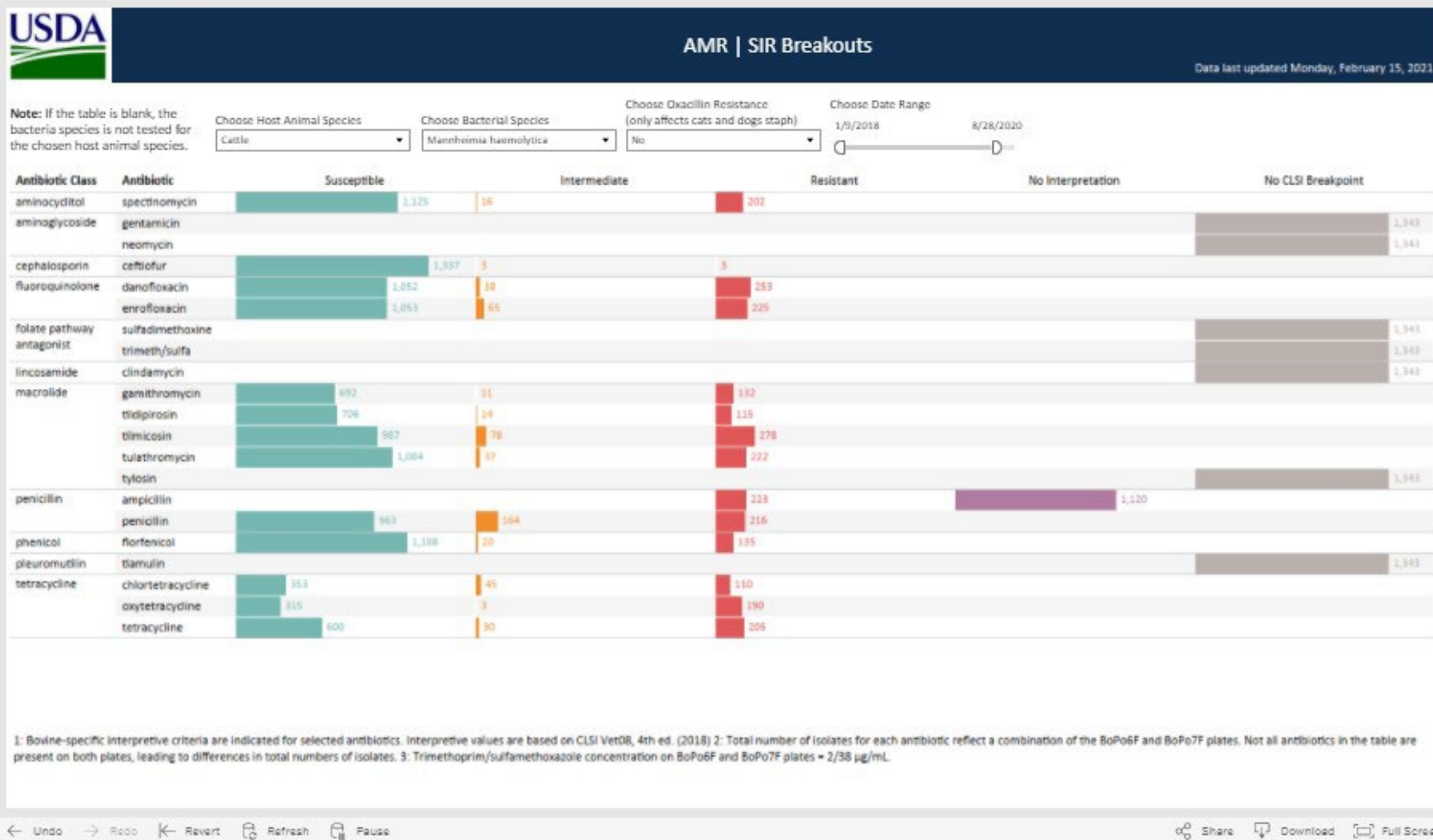
Collaboration with Industry &
University Partners

National Animal Health Monitoring System (NAHMS)





Recent NAHMS Studies



U.S. Department of
Agriculture

[Return to top](#)

National Animal
Health
Laboratory
Network AMR
Pilot Project

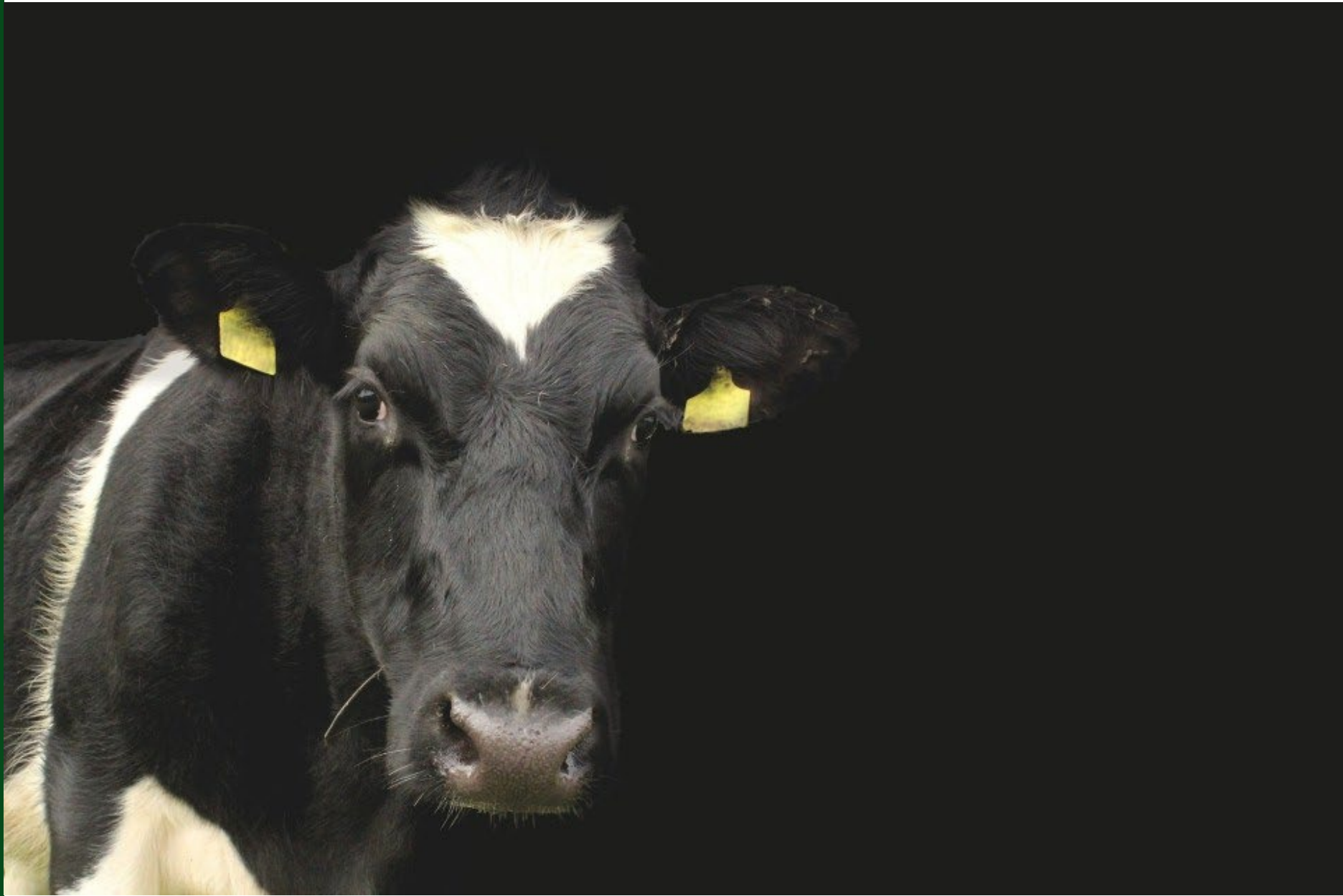


National Veterinary Accreditation Program

Swine Industry Collaboration



Dairy Industry Collaboration



Collaboration



Producers



Veterinarians




Diagnostic Laboratories

Communication

Year 3 report: 2020

USDA APHIS VS
National Animal
Health Laboratory
Network (NAHLN)
Antimicrobial
Resistance Pilot
Project

Introduction to APHIS AMR Pil... Participating Laboratories MIC Table SIR Breakouts



AMR | MIC Table

Data last updated Thursday, September 1, 2022

Susceptible Intermediate Resistant No Interpretation No Breakpoint

Note: If table below is blank, the bacteria species is not tested for the chosen host animal species.

Choose Host Animal Species

Cattle

Choose Bacterial Species

Escherichia coli

Choose Oxacillin Resistance
(only cats and dogs staph)

No

Choose Date Range

1/1/2018

12/1/2021

Antibiotic Class	Antibiotic	Total	≤0.125	≤0.25	≈0.25	≤0.5	≈0.5	≤1	≈1	>1	≤2	≈2	>2	≤4	≈4	>4	≤8	≈8	>8	≤16	>16	≈32	>32	≈64	>64	≤256	>256
aminocyclitol	spectinomycin	2,020															69			1,137		171		106	537		
aminoglycoside	gentamicin	2,020						1,673			60				13			20		34	220						
	neomycin	2,020												1,349				32		30		95	514				
cephalosporin	ceftiofur	2,020		351			940		67		34				24		158	446									
fluoroquinolone	danofloxacin	2,020	1,537		26		53		31	373																	
	enrofloxacin	2,020	1,528		39		42		41		11	359															
folate pathway antagonist	sulfadimethoxine	2,020																							749	1,271	
	trimeth/sulfa	2,020									1,345		675														
lincosamide	clindamycin	2,020		1											1			2		6	2,010						
macrolide	gamithromycin	858						6			14				167		508	163									
	tilidipirosin	858						9			58				494		263			20	14						
	tlmicosin	2,020									1			4	1		6		9	848	84			637	430		
	tulathromycin	2,020						2			18				176		676	608		408	73			18	41		
	tylosin	2,020				1					2					3				1		2	2,011				
penicillin	ampicillin	2,020		5			3		44		439				443		22		9	1,055							
	penicillin	2,020	1		2				2		1				1		14	1,999									
phenicol	florfenicol	2,020					2		7		194				845		216	756									
pleuromutilin	tiamulin	2,020							1						1		5		13		98	1,902					
tetracycline	chlortetracycline	1,162				7			81		159				78		39	798									
	oxytetracycline	1,162				4			150		153				14		4	837									
	tetracycline	858				7			172		118				4		15	542									

1: Bovine-specific interpretive criteria are indicated for selected antibiotics. Interpretive values are based on CLSI VET015, 5th ed. (Oct 2020). 2: Total number of isolates for each antibiotic reflect a combination of the BoPo6F and BoPo7F plates. Not all antibiotics in the table are present on both plates, leading to differences in total numbers of isolates. 3: Ceftiofur breakpoints have been established for mastitis cases only for E. coli infections in cattle. 4: Ampicillin breakpoints have been established for metritis cases only for E. coli infections in cattle. 5: Trimethoprim/sulfamethoxazole concentration on BoPo6F and BoPo7F plates = 2/38 µg/mL.

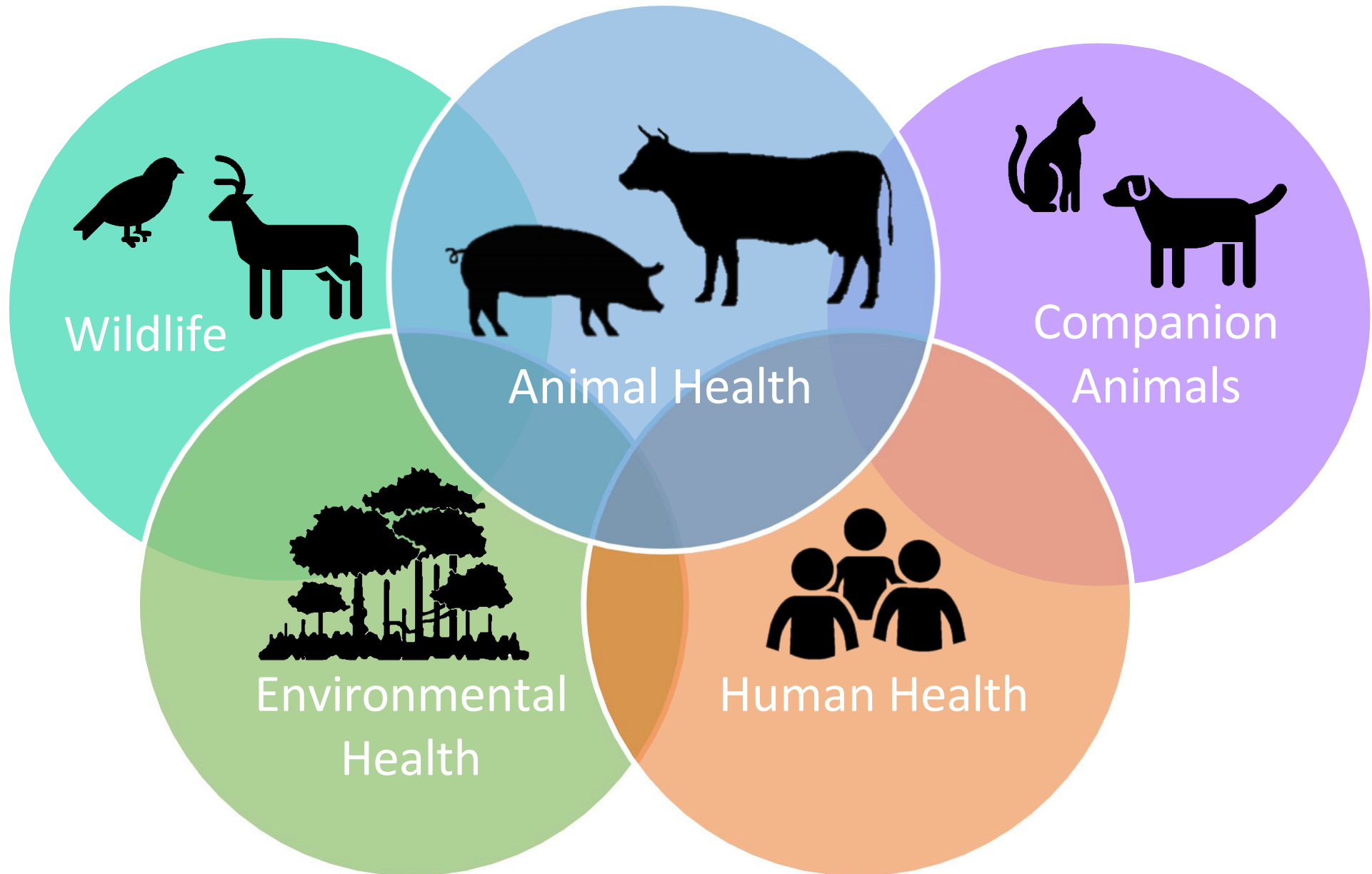
Science-Based Approach



Future Antimicrobial Use & Resistance Activities



U.S. Department of
Agriculture



Thank You!

Chelsey Shivley, DVM, PhD, DACAW
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DR. MEGIN NICHOLS

Veterinary Epidemiologist,
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Antimicrobial Stewardship in Agriculture: How Far Have We Come and What's Next?

Lessons learned from human illness outbreaks linked to animal contact

Megin Nichols, DVM, MPH, DACVPM

Division of Foodborne, Waterborne, and Environmental Diseases

Centers for Disease Control and Prevention

September 27, 2022

Steps in an OUTBREAK INVESTIGATION

DETECT A possible outbreak



FIND Cases in an outbreak



GENERATE Hypotheses through interviews



TEST Hypotheses through analytic studies and laboratory testing



SOLVE Point of contamination and original source of outbreak vehicle



CONTROL Outbreak through recalls, facility improvements, and industry collaboration



DECIDE An outbreak is over



If cases continue

Not finding associations

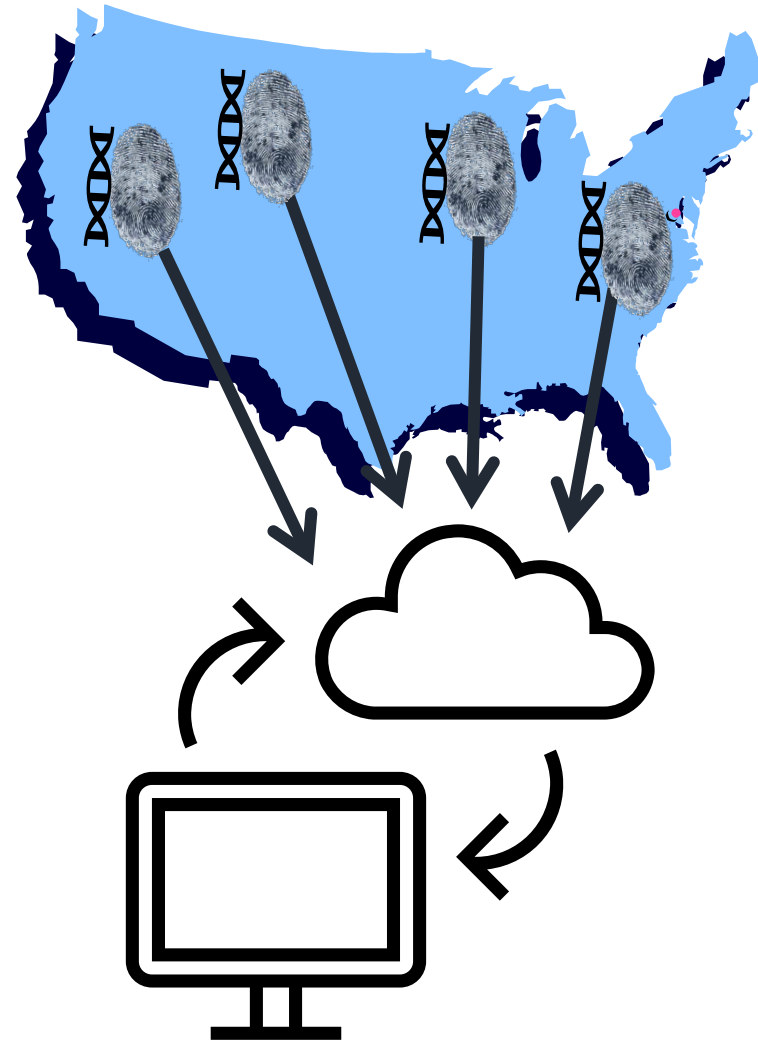
If cases stop

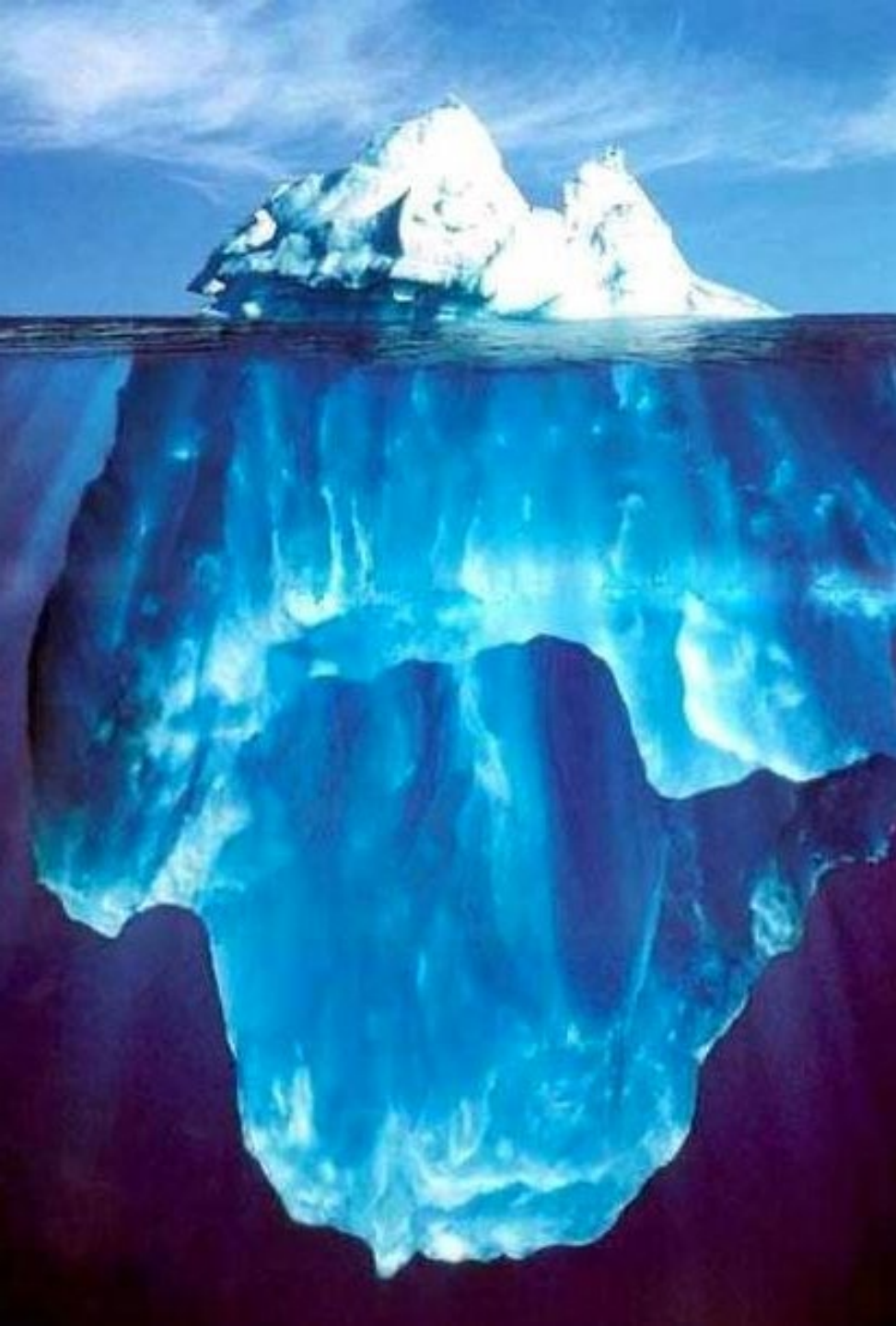
What is an outbreak?

- When two or more people get the same illness and investigation shows it came from the same contaminated food or drink, or contact with the same species of animal, the event is called a disease outbreak

Detecting Outbreaks with PulseNet

- WGS data from illness-causing bacteria uploaded to the PulseNet USA database
- Monitored for temporal and geographic clustering
- When a cluster is identified, PulseNet notifies epidemiologists





PulseNet-confirmed cases represent the tip of the iceberg

Salmonella (non-typhoidal)

- Under-reporting/under-diagnosis multiplier: 29.3



Groups at higher risk from enteric zoonoses

- Higher risk for infection
 - Young children (<5 years)
- Higher risk for adverse outcomes
 - Older adults (>65 years)
 - Young children (< 5 years)
 - People with weakened immune systems

Occupational

- Ranchers
- Dairy workers
- Veterinarians
- Slaughterhouse workers
- Postal workers
- Pet store workers
- Zookeepers



What have we learned
through investigation of
outbreaks linked to livestock?

One Health Response to a Multidrug-Resistant (MDR) *Salmonella* Heidelberg Outbreak



ZOONOTIC OUTBREAK



A new strain of *Salmonella* caused outbreaks of severe illness in dairy calves and people, mostly children.



LABORATORY INVESTIGATION

Laboratory testing detected infections across multiple states from the same strain and identified a new antibiotic resistance gene.



OUTBREAK RESPONSE



Public health, animal health, environmental, and agricultural experts worked together to track the spread of this strain and teach about infection prevention.

Salmonella Contamination

AND DAIRY CALF PRODUCTION

Outbreaks of multidrug-resistant *Salmonella* in humans have been linked to dairy calves. CDC supported The Ohio State University and University of Wisconsin-Madison to study contamination in dairy calf production.

Percentages of environmental samples with *Salmonella*. Many were resistant to antibiotics.



97% IN LIVESTOCK
MARKET



22% IN BARN



74% IN TRAILERS



93% IN HOLDING
PENS

Improving infection control throughout calf production will reduce the spread of antibiotic-resistant *Salmonella* in people, animals, and the environment.

Stewardship Defined

- Antimicrobial stewardship refers to the actions veterinarians take individually and as a profession to preserve the effectiveness and availability of antimicrobial drugs through conscientious oversight and responsible medical decision-making while safeguarding animal, public, and environmental health.

https://www.avma.org/sites/default/files/resources/AntimicrobStewardshipDef_Cor ePrinciplesFlyer_052318.pdf

Survey of production animal veterinarians' prescription practices, factors influencing antimicrobial drug use, and perceptions of and attitudes toward antimicrobial resistance

Daniel D. Taylor DVM, MPH

Jennifer N. Martin PhD

Paul S. Morley DVM, PhD

Keith E. Belk PhD

Alice E. White MS

Elaine J. Scallan Walter PhD

From the Colorado Integrated Food Safety Center of Excellence, Colorado School of Public Health, Aurora, CO 80045 (Taylor, White, Scallan Walter); and Department of Animal Sciences, College of Agricultural Sciences (Martin, Belk), and Department of Clinical Sciences, College of Veterinary Medicine and Biomedical Sciences (Morley), Colorado State University, Fort Collins, CO 80523. Dr. Morley's present address is the Veterinary Education, Research, and Outreach Center, West Texas A&M University, Canyon, TX 79016.

Address correspondence to Dr. Taylor (daniel.d.taylor@ucdenver.edu).

OBJECTIVE

To assess production animal medicine veterinarians' prescription practices and identify factors influencing their use of antimicrobial drugs (AMDs) and their perceptions of and attitudes toward antimicrobial resistance (AMR).

SAMPLE

157 production animal veterinarians in the United States.

PROCEDURES

An online cross-sectional survey and digital diary were used to gather information regarding perceptions on AMD use and AMR and on treatment recommendations for production setting-specific disease scenarios. Results were compared across respondents grouped by their selected production setting scenarios and reported years as veterinarians.

RESULTS

The most commonly selected production setting disease scenarios were dairy cattle (96/157 [61.1%]), backgrounding cattle (32/157 [20.4%]), and feedlot cattle (20/157 [12.7%]). Because few respondents selected swine (5/157 [3.2%]) or poultry (4/157 [2.5%]) scenarios, those responses were excluded from statistical analysis of AMD prescription practices. Most remaining respondents (147/148 [99.3%]) reported that they would recommend AMD treatment for an individual ill animal; however, responses differed for respondents grouped by their selected production setting scenarios and reported years as veterinarians when asked about AMD treatment of an exposed group or high-risk disease-free group. Most respondents reported that government regulations influenced their AMD prescribing, that owner and producer compliance was a veterinary-related factor that contributed to AMR, and that environmental modifications to prevent disease could be effective to mitigate AMR.

CONCLUSIONS AND CLINICAL RELEVANCE

Results of the present study helped fill important knowledge gaps pertaining to prescription practices and influencing factors for AMD use in production animal medicine and provided baseline information for future assessments. This information could be used to inform future interventions and training tools to mitigate the public health threat of AMR. (*J Am Vet Med Assoc* 2020;257:87–96)

Actions For Veterinarians

Veterinarians can slow antibiotic resistance by implementing disease prevention strategies and improving the use of antibiotics while also guaranteeing high-quality medical care for animal patients.



Prevent Disease



Maintain Accurate Records of Treatment & Outcomes



Stay Current



Clean Your Hands & Equipment



Select & Use Antibiotics Appropriately



Prevent Environmental Contamination



Commit to Antibiotic Stewardship

Antibiotic Stewardship Education

FOR CALF PRODUCERS

CDC supported The Ohio State University to develop and test antibiotic use decision-making tools and a training program for calf producers.



Dairy calf producers often need to decide whether antibiotics are needed using veterinary protocols. Giving antibiotics when they are not needed contributes to antibiotic resistance.



Antibiotic use knowledge test scores improved by about 20% after introduction of tools and training.



Farms receiving tools and training used fewer antibiotics than control farms. More data is needed to confirm the impacts of these interventions over time.

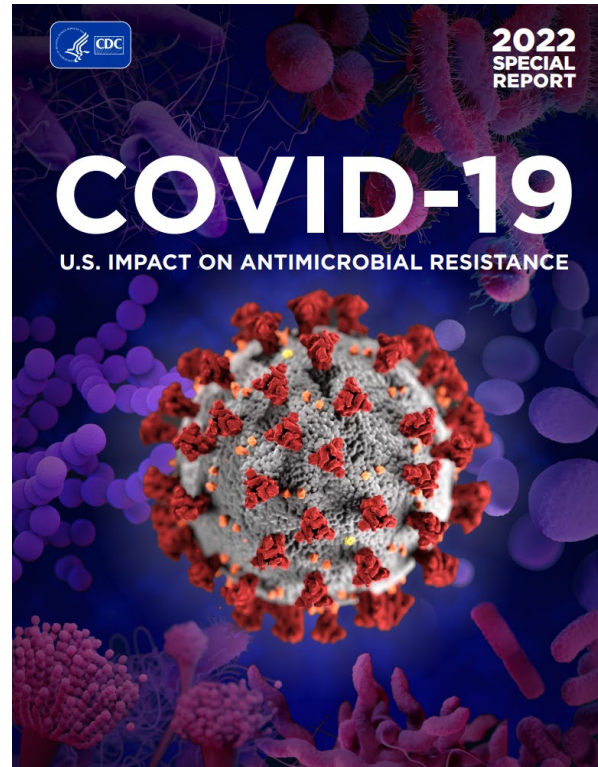
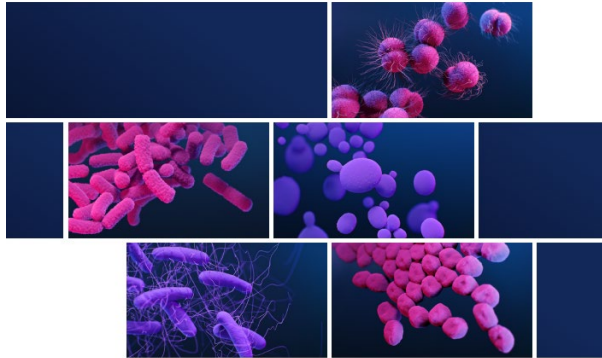
Educating calf producers on antibiotic stewardship can help reduce unnecessary antibiotic use.



<https://youtu.be/tr5EgQBc770>

ANTIBIOTIC RESISTANCE THREATS IN THE UNITED STATES

2019



INVESTING IN INNOVATION, 2016-2020



 **What's Next:** CDC is exploring investments in the U.S. public health infrastructure to better respond to the challenges of antimicrobial resistance and emerging threats simultaneously.

- Supporting more innovation and research on therapeutics, vaccines, and diagnostics.
- Enhancing interagency collaborations to accelerate research for developing new antibiotics, antifungals, therapeutics, and vaccines, including working with FDA to identify ways to support decolonization products.
- Working to undo negative impacts the COVID-19 pandemic may have had on essential vaccine conversations.
- Supporting the widespread use of vaccines to prevent infections, slow the spread of resistance, and reduce antibiotic use.
- Building a vaccine data platform to inform and accelerate the development of new vaccines, stopping infections before they start, as part of the CARB National Action Plan.



AVMA/Committee on Antimicrobials

ANTIMICROBIAL RESISTANT PATHOGENS AFFECTING ANIMAL HEALTH IN THE UNITED STATES



	Aminoglycosides	Amphenicols	Carbapenems	Cephalosporins	Fluoroquinolones	Lincosamides	Macrolides	Penicillins	Pleuromutilins	Sulfonamides	Tetracyclines	Trimethoprim
<i>Aeromonas</i> spp		●									●	●
<i>Campylobacter</i> <i>Jejuni</i>	●				●	●	●				●	
<i>Edwardsiella</i> spp		●									●	●
Enterobacteriaceae	● ● ●	●		● ● ●	●			●*		● ●	● ● ●	●
<i>Enterococcus</i> spp					●*		●	●				
<i>Flavobacterium</i> <i>Psychrophilum</i>		●									●	●
<i>Moraxella</i> spp							●				●	
<i>Ornithobacterium</i> <i>Rhinotracheale</i>								●		●	●	
Pasteurellaceae					● ●		●	● ●	●	●	● ●	
<i>Psuedomonas</i> <i>Aeruginosa</i>	●		● ●		● ●							
<i>Salmonella</i>	●	●		●	●		●	●	●	●	●	
<i>Staphylococcus</i> spp	●			●	●	●	● ●	● ●			● ●	●
<i>Streptococcus</i>				●	●			●				
<i>Vibrio</i>	●	●		●	●		●	●		●	●	●

● Fish & Shrimp ● Cattle ● Dogs & Cats ● Equine ● Chickens & Turkeys ● Sheep & Goats ● Swine

*Note: Some of the resistance noted for these organisms has been long-established and there available therapeutic options which may be successfully used for treatment.



CHICKEN

One of the risks of antimicrobial use in poultry is that resistant pathogens may spread to humans. Therefore, any use of antimicrobials in poultry should include measures to prevent the spread of resistance.

Antimicrobial resistance in poultry can impact human health and the environment.

Antimicrobial resistance has been documented in turkey health and can have significant economic and preserving the efficacy of antimicrobials.

PATHOGEN OF CONCERN:

- *Moraxella* spp.
 - *M. bovis*
 - *M. bovoculi*
- *Bovine respiratory disease*
 - *Mannheimia haemolytica*
 - *Pasteurella multocida*
 - *Histophilus somni*

Antimicrobial-resistant infections affecting cattle can have significant impacts on herd health, animal welfare, and economic consequences for cattle producers.

PATHOGEN OF CONCERN:

- *Escherichia coli*
- *Ornithobacterium rhinotracheale* (turkeys)
- *Pasteurella multocida*

Infections in broiler and layer chickens, and turkeys, can impact animal health. More research is needed regarding methods to prevent and control infections.

PATHOGEN

- *Staphylococcus aureus*
- *Enterobacteriaceae*
 - *Escherichia coli*
 - *Proteus* spp.
 - *Enterobacter* spp.
 - *Klebsiella* spp.
- *Pseudomonas aeruginosa*

Preserving the effectiveness of antimicrobials currently in use is crucial to preventing and controlling infections.

PATHOGEN OF CONCERN:

- *Staphylococcus aureus*
- *Streptococcus* spp.
- *Campylobacter jejuni*

Antimicrobial-resistant infections affect sheep and goats. Preventing infections through good milking practices, vaccine use—when available—and using diagnostic testing to rapidly identify pathogens affecting herd health are crucial to preventing all infections, including resistant infections.

PATHOGEN

- *Escherichia coli*
- *Streptococcus*
- *Pasteurella*
- *Salmonella*
 - *S. Choleraesuis*
 - *S. enterica*
 - *S. enteritidis*

Infections in farm animals can impact animal health and the environment.

PATHOGEN OF CONCERN:

- *Edwardsiella* spp.
 - *E. ictaluri*
 - *E. piscicida*
- *Aeromonas* spp.
 - *A. salmonicida*
 - *A. hydrophila*
 - *A. liquefaciens*
- *Flavobacterium psychrophilum*
- *Vibrio parahaemolyticus*
- *Vibrio vulnificus*

Antimicrobial-resistant infections affecting fish and shrimp can have significant economic and health impacts on animals and the environment.

FISH & SHRIMP

Antimicrobial resistance has been documented in bacterial pathogens that affect aquatic animal health and can have significant economic consequences. Therefore, preventing infections and preserving the efficacy of antimicrobials to treat, prevent and control infections is crucial.

What you need to know

- Some antimicrobial drugs used in aquatic animal medicine are available through over-the-counter and online sales, many of which are prohibited. Their extralabel use may be illegal, potentially compromising our ability to treat both aquatic animal and human infections. Taking these prohibited antimicrobials off the market may help reduce the development and spread of antimicrobial resistance.
- Antimicrobial-resistant aquatic animal and human pathogens have been found in fish and shellfish.

WHAT VETERINARIANS CAN DO:

- Maintain strict biosecurity practices to prevent or minimize the spread of disease within an aquaculture facility.
 - Enact proactive management techniques in fish culture settings, such as: Remove dead or moribund fish as soon as possible.
 - Reduce fish stressors as much as possible.
 - Monitor fish for signs of early infection.
- Provide judicious and evidence-based stewardship approaches to antimicrobial use.

Available at:

<https://www.avma.org/resources-tools/one-health/antimicrobial-use-and-antimicrobial-resistance>

Antibiotic Resistance (AR)

- Bacteria can develop the ability to defeat the drugs designed to kill them.
 - These bacteria can spread between people, animals and the environment
- Antibiotics save lives, but anytime they are used, they can lead to antibiotic resistance.
- AR affect the health of both people and animals.



U.S. Department of
Health and Human Services
Centers for Disease
Control and Prevention

For more information, please visit:
<https://www.cdc.gov/healthypets/pets-and-antibiotic-resistance.html>

CS 314413-A

Want to learn more about enteric zoonotic outbreaks and antimicrobial resistance?

<https://www.cdc.gov/healthypets/outbreaks.html>

<https://www.cdc.gov/healthypets/keeping-pets-and-people-healthy/pets-and-antibiotic-resistance.html>

For more information, contact CDC
1-800-CDC-INFO (232-4636)
TTY: 1-888-232-6348 www.cdc.gov

The findings and conclusions in this report are those of the authors and do not necessarily represent the official position of the Centers for Disease Control and Prevention.

Healthy Pets, Healthy People

CDC > Healthy Pets, Healthy People

- Information about COVID-19, Pets, & Other Animals +
- Keeping Pets and People Healthy +
- Pets & Other Animals +
- Diseases +
- Specific Groups & Settings +
- US Outbreaks -**
 - Solving Outbreaks
- Educational Materials +
- Connect With Us +
- New & Noteworthy



US Outbreaks of Zoonotic Diseases Spread between Animals & People

Below is a selected list from CDC of outbreaks of human infections linked to contact with animals and animal products in the United States. This list is not comprehensive, and outbreaks may have occurred that are not included here.

Animal Products

2019
[Pig Ear Dog Treats](#) – Multidrug-resistant *Salmonella* I 4, [5], 12:i:-

2012
[Dry Dog Food](#) – *Salmonella* Infantis

2007
[Dry Pet Food](#) – *Salmonella* Schwarzengrund

Cattle

2016
[Dairy Bull Calves](#) – *Salmonella* Heidelberg

Dogs

2019
[Pet Store Puppies](#) – *Campylobacter* Infections

Reptiles and Amphibians

2022
[Small Turtles](#) – *Salmonella*
[Bearded Dragons](#) – *Salmonella*

2021
[Small Turtles](#) – *Salmonella* Typhimurium

2020
[Pet Bearded Dragons](#) – *Salmonella* Muenster
[Pet Turtles](#) – *Salmonella* Typhimurium

2019
[Pet Turtles](#) – *Salmonella* Oranienburg infections

2017
[Pet Turtles](#) – *Salmonella* Agbeni Infections

2015
[Small Turtles](#) – *Salmonella* Sandiego, *Salmonella* Poona
[Pet Crested Geckos](#) – *Salmonella* Muenchen

ANTIBIOTIC RESISTANCE THREATS IN THE UNITED STATES

2019



U.S. Department of
Health and Human Services
Centers for Disease
Control and Prevention

DRUG-RESISTANT **CAMPYLOBACTER**

PUPPIES MADE PEOPLE SICK

How could an adorable puppy cause her owner to have a month-long hospital stay, including multiple stays in the intensive care unit? That is what happened to Mike, a 67-year-old retired professor with an existing chronic disease. Within a week of bringing home puppy Mabel from a pet store, Mike experienced diarrhea, fatigue, and lower back pain. The pain became excruciating and he was hospitalized with failing kidneys.



Mike was one of 113 people across 17 states identified as part of an outbreak of multidrug-resistant *Campylobacter* infections linked to pet store puppies. Only one type of antibiotic was able to treat his resistant infection. Due to complications from this infection and his chronic disease, he needed surgery to remove a dead section of stomach. Three months later, Mike finally felt well enough to return to post-retirement work at a bookstore. He still enjoys his pup, but is careful to wash his hands when cleaning up after her.







DR. ALISON ROBERTSON

Professor and Extension Field Crops Pathologist,
Department of Plant Pathology and Microbiology,
Iowa State University

Stewardship of antifungals in crop production

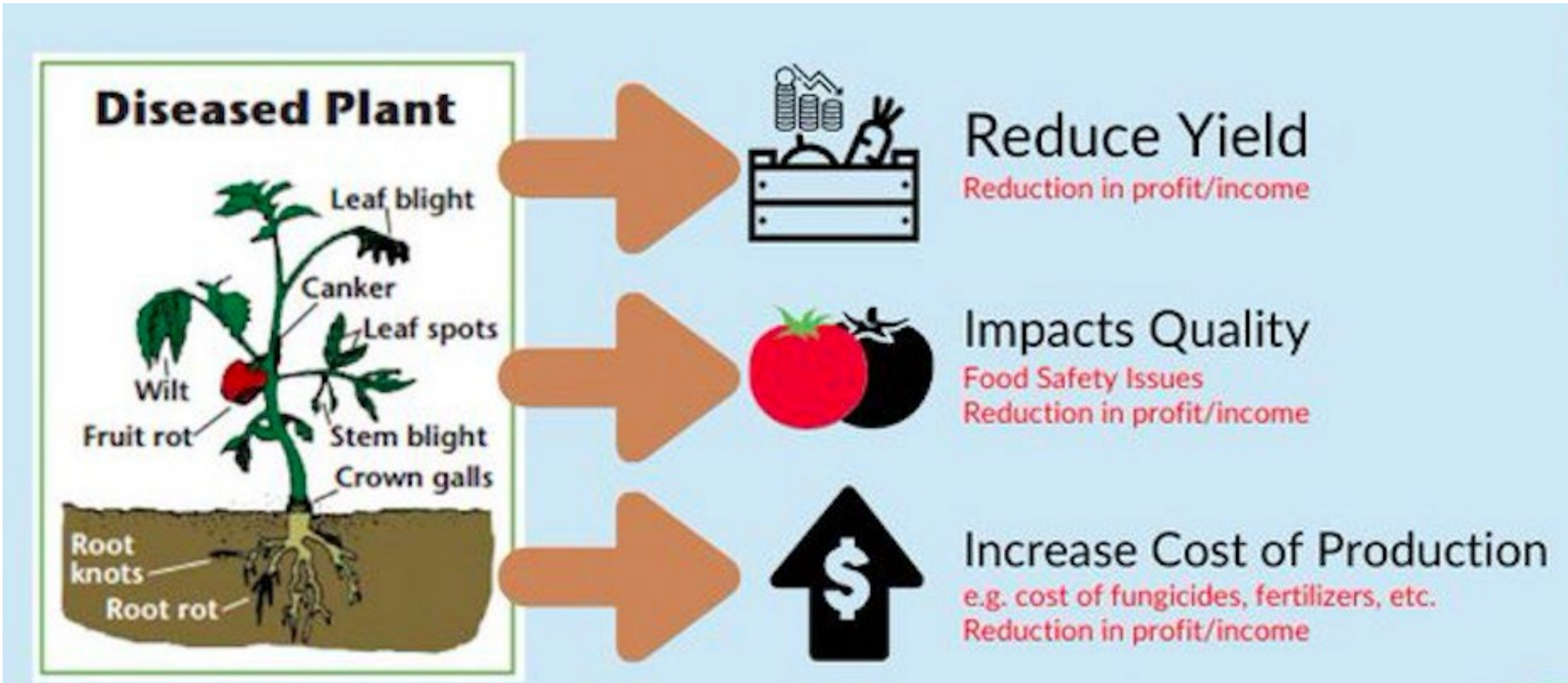


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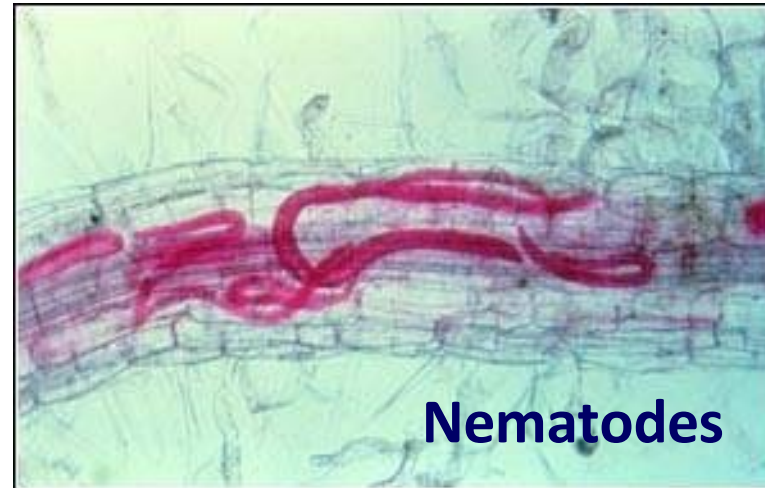
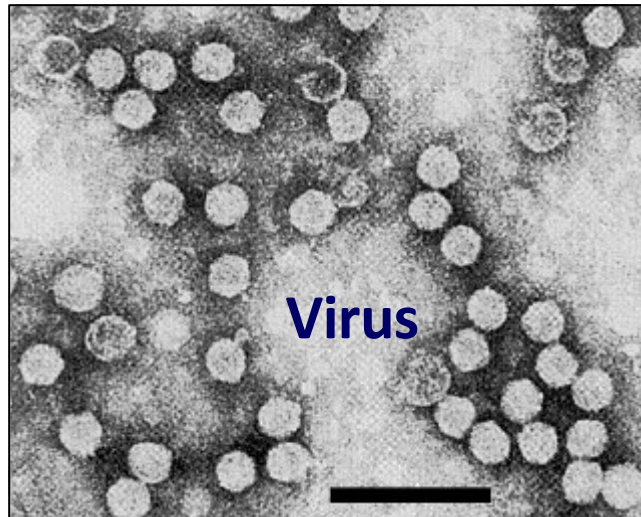
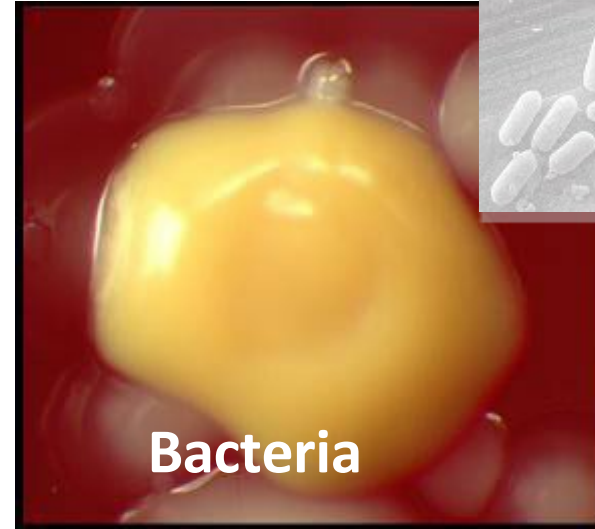
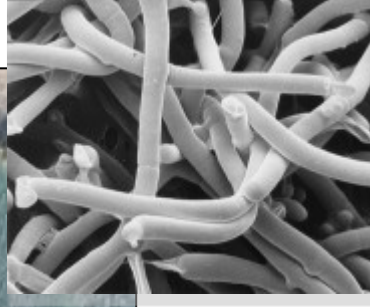
Plants get sick too!



Why are plant diseases important?



What causes disease in plants?



How do we treat plant disease?



How do we treat plant disease?

1. Plant disease resistant cultivars
2. Fungicide applications (seed and foliar)
3. Cultural methods (crop rotation, planting date, manage crop residue, etc.)



How do we treat plant disease?

1. Plant resistant cultivars
2. Fungicide applications (seed and foliar) = Antifungals
3. Cultural methods (crop rotation, planting date, manage crop residue)



Antifungals used to treat field crop disease

45 FRAC (mode of action) groups



Fungicide Resistance Action Committee
*****.frac.info

3-7 FRAC groups primarily
used on field crops



FUNGICIDE CLASSIFICATION

Repeated use of fungicide with the same mode of action can result in the selection of fungicide-resistant strains of plant pathogens.

by MODE OF ACTION (MOA)

The numbers groups fungicides by their mode of action to assist the selection of fungicides to maintain greater diversity in fungicide use and to avoid using fungicides with different modes of action to delay the development of fungicide resistance.

FRAC CODE	MODE OF ACTION	CHEMICAL FAMILY	ACTIVE INGREDIENT	PRODUCT EXAMPLES
MITOCHONDRIAL INHIBITORS				
3	14S: Inhibits mitochondrial complex II in various species of fungi	Strobilurins	Trifluromethylpyridine	Spinelor, Spinelor Pro, and Spinelor Pro Max
CELL MEMBRANE INHIBITORS				
9	11: Inhibits ergosterol synthesis in fungi	azoxystrobin	Alto, azoxystrobin, and azoxystrobin Pro	ATLANTIC
		fenpropimorph	Conquest, Conquest Pro, and Conquest Pro Max	ATLANTIC
		fenpropidin	Depend, Depend Pro, and Depend Pro Max	ATLANTIC
		fenpropat	Depend, Depend Pro, and Depend Pro Max	ATLANTIC
		fenpropat	Depend, Depend Pro, and Depend Pro Max	ATLANTIC
		fenpropat	Depend, Depend Pro, and Depend Pro Max	ATLANTIC
RESPIRATORY INHIBITORS				
5	11: Inhibits mitochondrial complex II in various species of fungi	azoxystrobin	Alto, azoxystrobin, and azoxystrobin Pro	ATLANTIC
		fenpropimorph	Conquest, Conquest Pro, and Conquest Pro Max	ATLANTIC
		fenpropidin	Depend, Depend Pro, and Depend Pro Max	ATLANTIC
		fenpropat	Depend, Depend Pro, and Depend Pro Max	ATLANTIC
		fenpropat	Depend, Depend Pro, and Depend Pro Max	ATLANTIC
		fenpropat	Depend, Depend Pro, and Depend Pro Max	ATLANTIC
OXIDATIVE PHOSPHORYLATION INHIBITORS				
29	11: Inhibits mitochondrial complex II in various species of fungi	oxathiopyrimidines	Prothioconazole	Prothioconazole
MULTI-SITE CONTACT ACTION				
18	11: Inhibits ergosterol synthesis in fungi	strobilurins	Trifluromethylpyridine	Spinelor, Spinelor Pro, and Spinelor Pro Max

Take Action is endorsed by the following organizations:

For more information and links to additional resources, visit www.NVIRelution.com

by PREMIX

This section lists premix fungicides by their trade names to help you identify the premix, fungicide, and their respective mode of action groups. Refer to the Mode of Action section on the left for more information.

PREMIX	ACTIVE INGREDIENT	FRAC CODE
ATLANTIC	Trifluromethylpyridine	3
ATLANTIC	Trifluromethylpyridine	3
ATLANTIC	Trifluromethylpyridine	3
ATLANTIC	Trifluromethylpyridine	3
ATLANTIC	Trifluromethylpyridine	3
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ATLANTIC	Trifluromethyl	

Antifungals used to field crop disease

FRAC Group 3 Demethylation Inhibitors (DMI)

FRAC Group 7 Succinate dehydrogenase inhibitors (SDHI)

FRAC Group 11 Quinone outside inhibitors (QOI)

FUNGICIDE CLASSIFICATION

Repeated use of fungicides with the same mode of action can result in the selection of fungicide-resistant strains of plant pathogens.

Take ACTION
Fungicide Resistance Management

by MODE OF ACTION (MOA)

The following fungicides are listed by their mode of action (MOA) according to the Fungicide Resistance Action Committee (FRAC). Fungicides are listed by their FRAC code, which is a number that identifies the mode of action. Fungicides with the same mode of action are listed together. Fungicides with different modes of action are listed separately.

by FRAC CODE

The following fungicides are listed by their FRAC code. Fungicides with the same FRAC code are listed together. Fungicides with different FRAC codes are listed separately.

FRAC CODE	MODE OF ACTION	CHEMICAL FAMILY	ACTIVE INGREDIENT	PRODUCT EXAMPLES
1	ACETYL COA CARBOXYLASE INHIBITORS	Triazole	Prochloraz	Prochloraz
3	DEMETHYLATION INHIBITORS	Triazole	Prochloraz	Prochloraz
7	SUCCINATE DEHYDROGENASE INHIBITORS	Triazole	Prochloraz	Prochloraz
11	QUINONE OUTSIDE INHIBITORS	Triazole	Prochloraz	Prochloraz


For more information and links to additional resources, visit www.iwilltakeaction.com/resources/fungicide-classification-chart

Antifungals used to treat field crop disease

Azoles ← FRAC Group 3 Demethylation Inhibitors (DMI)

FUNGICIDE CLASSIFICATION

Repeated use of fungicides with the same mode of action can result in the selection of fungicide-resistant strains of plant pathogens.



TakeAction
Responsible Agriculture






by MODE OF ACTION (MORA)






Use fungicides belonging to the same mode of action within the indicated fungicide MORA to maintain product efficacy at fungicide rates and 21 is listed among effective fungicides without different action to delay the development of fungicide resistance.






FAIR CODE	MODE OF ACTION	CHEMICAL FAMILY	ACTION MECHANISM	PRODUCT EXAMPLES
MITIGATING DISRUPTORS				
1	Cell wall synthesis inhibitors (cell wallase activity in fungi)	Triazolinone	Hydroxamate-acylase	Amistar, pyraclostrobin and pyraclostrobin
3	Cell membrane inhibitors/ enzymes (cell wallase activity in fungi)	ergosterol	alter cell membrane permeability	Protonect, pyraclostrobin
		demethylation	inhibition of sterol synthesis	Protonect, pyraclostrobin
		sterol	inhibition of sterol synthesis	Protonect, pyraclostrobin
		sterol	inhibition of sterol synthesis	Protonect, pyraclostrobin
		sterol	inhibition of sterol synthesis	Protonect, pyraclostrobin
		sterol	inhibition of sterol synthesis	Protonect, pyraclostrobin
RESPIRATION INHIBITORS				
3	Mitochondrial inhibitors/ cytochrome b5 reductase (cytochrome b5 reductase activity in fungi)	cytochrome b5 reductase	inhibition of cytochrome b5 reductase	Protonect, pyraclostrobin
		cytochrome b5 reductase	inhibition of cytochrome b5 reductase	Protonect, pyraclostrobin
		cytochrome b5 reductase	inhibition of cytochrome b5 reductase	Protonect, pyraclostrobin
		cytochrome b5 reductase	inhibition of cytochrome b5 reductase	Protonect, pyraclostrobin
		cytochrome b5 reductase	inhibition of cytochrome b5 reductase	Protonect, pyraclostrobin
		cytochrome b5 reductase	inhibition of cytochrome b5 reductase	Protonect, pyraclostrobin
RELATIVE PHOSPHORYLATION UNCOUPLERS				
29	Inhibitor of phosphatase activity	Phosphatase	Phosphatase	Protonect, pyraclostrobin
RESISTANCE				
27	Inhibitor of phosphatase activity	Phosphatase	Phosphatase	Protonect, pyraclostrobin
MULTI-SITE CONTACT ACTIVITY				
85	Multi-site contact activity	Multi-site contact activity	Multi-site contact activity	Protonect, pyraclostrobin

FAIR CODE	ACTION MECHANISM	FAIR CODE
1	Cell wallase activity in fungi	1
3	Cell membrane inhibitors/ enzymes	3
29	Inhibitor of phosphatase activity	29
27	Inhibitor of phosphatase activity	27
85	Multi-site contact activity	85

TakeAction is endorsed by the following organizations:

For more information and links to additional resources, visit www.FAIRfungicide.com

Fungicide resistance is a global problem. It is caused by the repeated use of fungicides with the same mode of action. This leads to the selection of fungicide-resistant strains of plant pathogens. To maintain product efficacy, it is important to use fungicides with different modes of action. This is why the FAIR fungicide classification is so important. It helps growers to choose the right fungicide for their crop and to avoid the development of fungicide resistance.

Is use of DMIs to treat plant disease resulting in azole resistance in human health?

Commentary

A Section 508-conformant HTML version of this article is available at <https://doi.org/10.1289/EHP7484>.

Trends in Agricultural Triazole Fungicide Use in the United States, 1992–2016 and Possible Implications for Antifungal-Resistant Fungi in Human Disease

Mitsuru Toda,¹ Karlyn D. Beer,¹ Kathryn M. Kuivila,² Tom M. Chiller,¹ and Brendan R. Jackson¹

PLOS PATHOGENS

REVIEW

Fungicide effects on human fungal pathogens: Cross-resistance to medical drugs and beyond

Rafael W. Bastos¹, Luana Rossato², Gustavo H. Goldman^{1na*}, Daniel A. Santos^{3nb*}

Perspective



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Published online in Wiley Online Library: 24 July 2017

(wileyonlinelibrary.com) DOI 10.1002/ps.4607

Does agricultural use of azole fungicides contribute to resistance in the human pathogen *Aspergillus fumigatus*?

Derek Hollomon^{*}



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Fungicides are More Than a Plant Disease Management Tool

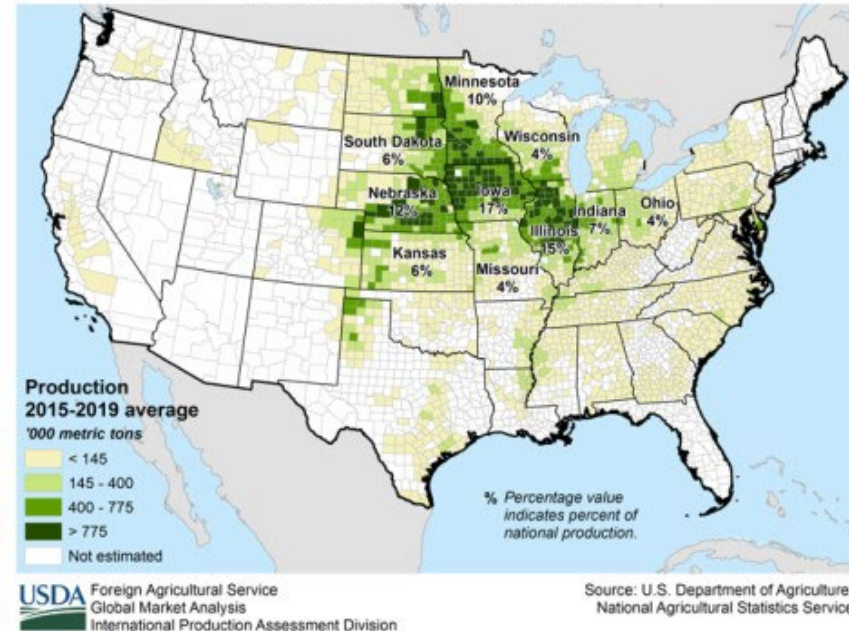
Published: 10/11/2021

DOI: doi.org/10.31274/cpn-20211011-000

CPN-4009

Field crop production in the U.S.

Corn

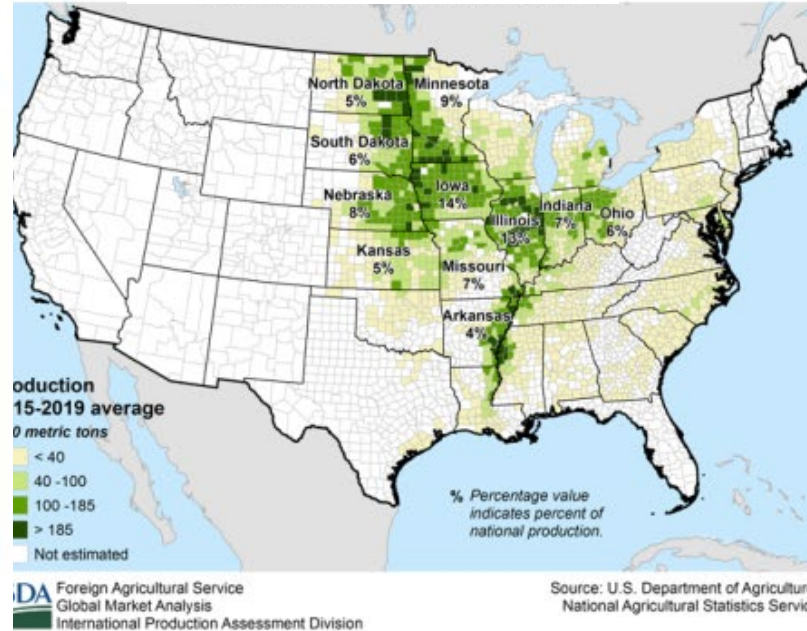


92.0 million acres in 2020



\$61 billion

Soybean

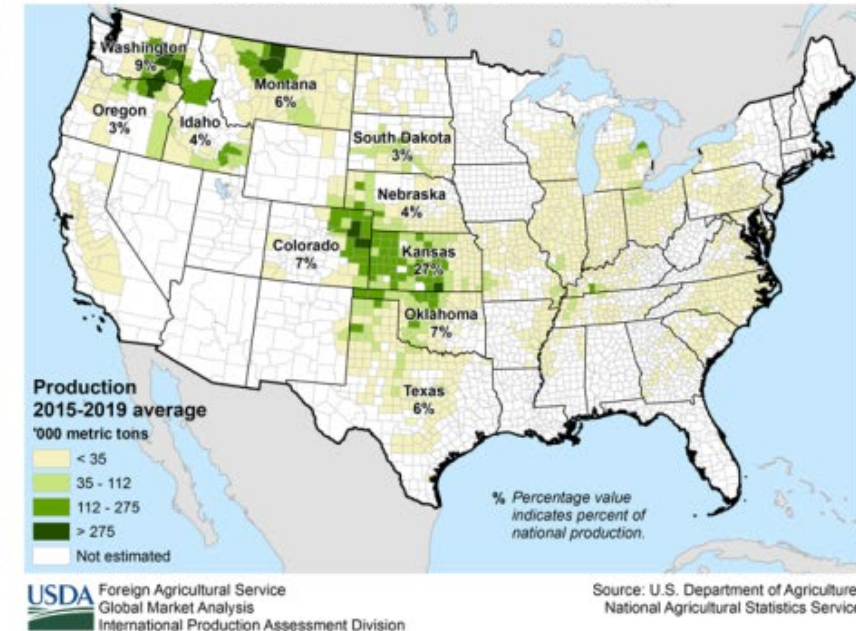


83.8 million acres in 2020



\$46.1 billion

Wheat



44.3 million acres in 2020



\$9.6 billion

Losses due to diseases of corn

2012 - 2021

2018 - 2021

Tar spot



45.4 – 231.3 mill. bu

=

\$0.64 - \$13.69/ac

Gray leaf spot



80.4 - 482.4 mill. bu

=

\$4.17 - \$19.89/ac

**Northern corn
leaf blight**



38.2 – 539.6 mill. bu

=

\$1.58 - \$22.98/ac

Southern rust







3.1 – 158.6 mill. bu

=

\$0.13 - \$6.08/ac

Losses due to diseases of corn

2012 - 2021			
2018 - 2021			
Tar spot	Gray leaf spot	Northern corn leaf blight	Southern rust
			
45.4 – 231.3 mill. bu = \$0.64 - \$13.69/acre	80.4 - 482.4 mill. bu = \$4.17 - \$19.89/acre	38.2 – 539.6 mill. bu = \$1.58 - \$22.98/acre	3.1 – 158.6 mill. bu = \$0.13 - \$6.08/acre

Treatment with antifungals mitigates losses

Plant pathogens also develop resistance

FUNGICIDE CLASSIFICATION

Repeated use of fungicides with the same mode of action can result in the selection of fungicide-resistant strains of plant pathogens.

by MODE OF ACTION (MoA)

The MoA groups fungicides by the mode of action within the selected fungicide MoA. This is a primary group. Fungicides are grouped into 21 MoA groups. Fungicides within the same MoA group are likely to have similar modes of action.

by PREMIX

The active ingredients in fungicides are listed in the table. Fungicides are listed by their active ingredients and their respective MoA. Fungicides are listed by their active ingredients and their respective MoA. Fungicides are listed by their active ingredients and their respective MoA.

FUNGICIDE CODE	MODE OF ACTION	CHEMICAL FAMILY	ACTIVE INGREDIENT	PRODUCT EXAMPLES	FUNGICIDE CODE	ACTIVE INGREDIENT	FUNGICIDE CODE
MITOCHONDRIAL DISRUPTORS							
1	1	1	1	1	1	1	1
CELL MEMBRANE DISRUPTORS							
2	2	2	2	2	2	2	2
CELL MEMBRANE DISRUPTORS (continued)							
3	3	3	3	3	3	3	3
RESPIRATION INHIBITORS							
4	4	4	4	4	4	4	4
CELL WALL DISRUPTORS							
5	5	5	5	5	5	5	5
PROTEIN SYNTHESIS INHIBITORS							
6	6	6	6	6	6	6	6
DNA/RNA SYNTHESIS INHIBITORS							
7	7	7	7	7	7	7	7
CELL DIVISION INHIBITORS							
8	8	8	8	8	8	8	8
CELL DIVISION INHIBITORS (continued)							
9	9	9	9	9	9	9	9
CELL DIVISION INHIBITORS (continued)							
10	10	10	10	10	10	10	10
CELL DIVISION INHIBITORS (continued)							
11	11	11	11	11	11	11	11
CELL DIVISION INHIBITORS (continued)							
12	12	12	12	12	12	12	12
CELL DIVISION INHIBITORS (continued)							
13	13	13	13	13	13	13	13
CELL DIVISION INHIBITORS (continued)							
14	14	14	14	14	14	14	14
CELL DIVISION INHIBITORS (continued)							
15	15	15	15	15	15	15	15
CELL DIVISION INHIBITORS (continued)							
16	16	16	16	16	16	16	16
CELL DIVISION INHIBITORS (continued)							
17	17	17	17	17	17	17	17
CELL DIVISION INHIBITORS (continued)							
18	18	18	18	18	18	18	18
CELL DIVISION INHIBITORS (continued)							
19	19	19	19	19	19	19	19
CELL DIVISION INHIBITORS (continued)							
20	20	20	20	20	20	20	20
CELL DIVISION INHIBITORS (continued)							
21	21	21	21	21	21	21	21
CELL DIVISION INHIBITORS (continued)							
22	22	22	22	22	22	22	22
CELL DIVISION INHIBITORS (continued)							
23	23	23	23	23	23	23	23
CELL DIVISION INHIBITORS (continued)							
24	24	24	24	24	24	24	24
CELL DIVISION INHIBITORS (continued)							
25	25	25	25	25	25	25	25
CELL DIVISION INHIBITORS (continued)							
26	26	26	26				

FRAC Group 11 Quinone outside inhibitors (QOI)

Field resistance in ~40 plant pathogens

Plant pathogens also develop resistance

Frogeye leaf spot



3.8– 53.4 mill. bu

==

\$0.56 - \$5.34/acre

FRAC Group 11 Quinone outside inhibitors (QOI)

Field resistance in ~40 plant pathogens

[illegible]

How far have we come and what's next?

Communication and education



How far have we come

Communication and education



CORN DISEASE MANAGEMENT
CPN-2011-W

Fungicide Efficacy for Control of Corn Diseases



SOYBEAN DISEASE MANAGEMENT
CPN-1019-W

Fungicide Efficacy for Foliar Soybean Diseases



SMALL GRAIN DISEASE MANAGEMENT
CPN-3002-W

Fungicide Efficacy for Control of Wheat Diseases



August 2–6, 2021

Seismic Shifts in Disease Risk

Plenary Speaker: Marin T. Brewer



Talk Title: *Does agricultural use of triazole fungicides contribute to antifungal resistance of *Aspergillus fumigatus* in humans?*

Bio: Dr. Marin Talbot Brewer is an Associate Professor of Mycology and Plant Pathology at the University of Georgia where she has been a faculty member since 2011. Her research focuses on the evolution and diversity of fungal threats to plants and people with interests in the genetic basis of disease emergence and host specialization, the evolution of fungicide resistance and fungal mating systems, and the taxonomy and systematics of fungi causing emerging plant diseases. She received her MS in Plant, Soil, and Environmental Science from the University of Maine where she studied the effects of biological and cultural controls on soil microbial ecology and *Rhizoctonia* disease of potato, and her PhD in Plant Pathology and Plant-Microbe Biology from Cornell University in 2011, where her dissertation focused on the phylogeography and mating system of the grape powdery mildew fungus, *Erysiphe necator*. Recent work in the Brewer lab is concentrated on azole resistance in the human pathogen *Aspergillus fumigatus* in environmental settings. Her research has been funded by diverse agencies including the National Science Foundation, the U.S. Department of Agriculture, and the Centers for Disease Control and Prevention.



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Fungicides are More Than a Plant Disease Management Tool

Published: 10/11/2021
DOI: doi.org/10.31274/cpn-20211011-000
CPN-4009

.... and what's next?

Fusarium Head Blight Prediction Center for Wheat



*****.wheatcab.psu.edu/

National Prediction Modeling Tool Initiative



*****agpmt.org/



Thanks for your attention



What other questions do you have?

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