**Testimony before the**

**House Committee on Energy and Commerce, Subcommittee on Health**

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**Gail R. Hansen, D.V.M., M.P.H.**
**Senior Officer, Human Health and Industrial Farming Campaign**
**The Pew Charitable Trusts**

Good afternoon Chairman Pallone, Chairman Waxman, Chairman Emeritus Dingell, Ranking Member Shimkus and members of the Health Subcommittee. My name is Gail Hansen and I am a Senior Officer with The Pew Charitable Trusts. I appreciate the opportunity to speak before you today about the routine use of antibiotics in food animal production.

I am a veterinarian who cares deeply about animal and human health and welfare. I have spent most of my professional career working to keep animals and people healthy. For 12 years, I was in private clinical practice, mostly in companion animals. For another 15 years I served in local and state public health departments; 12 years as the State Public Health Veterinarian and three as the top Kansas State Epidemiologist. In Kansas I was responsible for creating and implementing policy, for coordinating disease tracking and conducting outbreak investigation for all infectious diseases in the state. In addition, I served on the executive board of the National Association of State Public Health Veterinarians (NASPHV) for eight years and was the Infectious Disease Chair for the Council of State and Territorial Epidemiologists in 2007. I am a member of the American Veterinary Medical Association (AVMA) and was a U.S. Congressional Fellow for the AVMA from 2008-2009.

My message to you today is simple:

1) Antibiotics are overused in industrial farming to the detriment of human health. Antibiotic overuse has spurred generations of bacteria that are causing life threatening illnesses that were once easily treatable with antibiotics.

2) Effective alternatives are available to agribusiness. This has been demonstrated by practices adopted abroad, as well as in the United States.

3) Congress has the opportunity to enact legislation that will curtail the use of antibiotics in industrial food animal production without having significant economic impact on the industry.

*<u>The health risks posed by antibiotic use in industrial farming</u>*: Industrial farming routinely and extensively incorporates low dose concentrations of antibiotics in the feed and water of healthy food animals for growth promotion, feed efficiency and other uses where the animal has not been exposed to disease. A wide range of antibiotics, such as penicillin and tetracycline, are available over the counter for use in food animal production in this country[1]. The United States Food and Drug Administration (FDA) allows this practice under its current rules and regulations and yet almost none of the over the counter uses have been reviewed by the FDA to ensure they are safe with respect to antibiotic resistance.

FDA approved over-the-counter antibiotic sales more than 50 years ago when our understanding of the mechanics and implications of antibiotic resistance was still in its infancy and the largest safety concern was drug residues in meat. The seven classes of antibiotics—lincosamides, sulfonamides, tetracylcines, aminoglycosides, macrolides, penicillin and streptogramins—deemed critically important for human use were never reviewed by FDA for implications to human health caused by antibiotic resistance. Today, the science of antibiotic resistance is more advanced and well-understood. The guidelines for **new** antibiotic approval and withdrawal have been updated to require resistance-related safety demonstration. However, the agency has said that it is extremely difficult for it to reevaluate previously approved drugs based on updated criteria.

In 1977, when FDA attempted to take steps to curtail antibiotic use, the agency's efforts were thwarted by Congress.[2] Even the recommendations of the nation's leading research institutions were ignored.[3]

In the 1980s, the National Research Council and Institute of Medicine warned of the dangers of overuse of antibiotics in food animals.[4] In 2003 the National Academy of Sciences, which were created by Abraham Lincoln in 1863 to serve as scientific advisors to Congress, stated: "Clearly, a decrease in the inappropriate use of antimicrobials in human medicine alone is not enough. Substantial efforts must be made to decrease inappropriate overuse of antimicrobials in animals and agriculture as well." [5]

These findings are of little surprise to those of us who have studied medicine. Every introductory microbiology class teaches that using antibiotics at levels that are below a therapeutic dose sets up a perfect environment for bacteria to develop resistance. We now know that resistance to antibiotics can develop rapidly, extend to other antibiotics in the same or different class and be shared among bacteria in a variety of ways; up to 95 percent of antibiotic resistance is from sharing genetic material for resistance[6].

Four decades of rigorous science and research confirm that the routine use of antibiotics in food animal production promotes the development of dangerous drug-resistant bacteria that can spread to humans. The notebook in front of me today contains 40 years of independent, peer-reviewed studies demonstrating this scientific link. I am submitting with my written testimony today an annotated bibliography summarizing this research.

Within this scientific literature one of the most compelling stories concerns Cipro®. Cipro® is an antibiotic that belongs to a class of drugs called fluoroquinolones and was a key antibiotic used to treat members of Congress and staff after the anthrax attack in October 2001. In Australia, where fluoroquinolones have never been approved for use in food animal production, domestically acquired human infections with Cipro®-resistant Campylobacter are still either absent or rare[7]. This is in stark contrast to the situation in the U.S., where fluoroquinolone use in poultry was common from 1995 to 2005. There was controversy within the veterinary community about whether it should be allowed in poultry water due to the concerns that it would lead to antibiotic resistance in humans. FDA monitored resistance and saw that resistance to Cipro® in human illnesses was increasing at a rapid rate: from 12.9 percent in 1997 to 21.7 percent in 2005.[8] In comparison, Cipro®-resistant Campylobacter rates in the U.S. had held steady at about 1 percent for the 10 years it was used exclusively in human medicine. In response, FDA began the process to remove fluoroquinolones from routine use in poultry in 2000. The drug class was banned from routine poultry use in 2005 after protracted legal challenges.

Use of the antibiotic known as Avoparcin is another good example. Avoparcin is a drug that was widely used in Europe for growth promotion in animals, but not used in people. However, it was found to share resistance with a very closely related to and critically important human drug, vancomycin. Vancomycin is a powerful drug and is used only after treatment with other antibiotics has failed. In the countries where avoparcin was fed to livestock, animals had intestinal bacteria resistant to vancomycin as well. In the countries that didn't use avoparcin, including the U.S. and Sweden, livestock did **not** have intestinal bacteria resistant to vancomycin. When avoparcin use was banned in Denmark, a World Health Organization (WHO) report found that "the termination of [avoparcin] in Denmark has dramatically reduced the food animal reservoir of enterococci resistant to these growth promoters, and therefore reduced a reservoir of genetic determinants (resistance genes) that encode antimicrobial resistance to several clinically important antimicrobial agents in humans."[9] In English, this simply means that banning the use of avoparcin as a growth promoter has significantly reduced the number of antibiotic resistant bacteria.

There are additional examples of such links between antibiotic use in livestock and poultry and human cases of antibiotic resistance. For example, Dr. James Johnson, testifying today, is a prominent expert in the field of study connecting resistant urinary tract infections in women to resistant *E. coli* in food animals.[10]

*<u>There are proven alternatives for many uses of antibiotics in industrial farming:</u>* In contrast to the clear impacts on human health, the rationale for much of the antibiotic use in industrial farming is tenuous.

First, using antibiotics for growth promotion is an outdated practice and yields questionable benefits to farmers in modern agriculture. In U.S. studies, little or no benefits were seen with nontherapeutic antibiotic use in poultry.[11] A United States Department of Agriculture study found that in growing and finishing pigs, those that are 6 weeks to 5 months old, the benefits of using nontherapeutic antibiotics are so small that either none were found[12] or that they were insufficient to offset the expense of the antibiotics themselves.[13] In Denmark, experts presumed that antibiotics produced a 10 percent feed efficiency advantage, based on data from the 1950s, but in modern agriculture, more recent studies have found almost no effect on feed efficiency.[14] Even so, enormous numbers of animals are fed the drugs. By way of example, one drug company supplies antibiotics in feed for 632 million chickens per year.[15]

Second, it is not necessary, as some claim, to dispense antibiotics on a massive scale to protect food safety. On the contrary, rarely has food safety been shown to be adversely affected by decreasing the amount of nontherapeutic antibiotics given to food animals. In fact, in the U.S., there were significant reductions in the types of foodborne illness normally acquired from eating chicken between 1995 and 2000, the same period that the poultry industry reduced antibiotic use.[16] Denmark data shows removal of in-feed antibiotics similarly had no negative impact on food safety.[17] FDA Principal Deputy Commissioner Dr. Joshua Sharfstein confirmed in his House Rules Committee testimony last year, "Eliminating these [growth promotion and feed efficiency] uses will not compromise the safety of food."[18]

This is not to say that antibiotics have no place in food animal production. As a veterinarian, I know that appropriate antibiotic use – to treat sick animals or prevent the spread of infection in animals at heightened risk – can be beneficial to animal and human health. But just as surely, inappropriate uses, where there is no disease present, are contrary to human health practices. Many other public health veterinarians and farmers agree with these principles and some have asked that I submit statements on their behalf with my written testimony.

It also is clear that antibiotics for animal use should be kept to the same standards used in human medicine. Bacterial resistance does not have a different effect on humans and animals. Resistance can transfer between species of bacteria. Antibiotics should be prescribed only to treat individuals and groups of animals exposed to disease. Over the counter use of antibiotics is not allowed in human medicine or for our pet dogs and cats and should not be allowed in food animal production.

The World Animal Health Organization (OIE), the Food and Agricultural Organization of the United Nations (FAO) and the WHO recognize that the animal and human health sectors have a shared responsibility to minimize antibiotic resistance.[19] And as all three have jointly stated, antimicrobial usage, if necessary, should always be a part of, not a replacement for, an integrated animal health program.[20] The routine use of antibiotics should never be a substitute for good animal health management and the routine use of antimicrobials in control programs should be regularly assessed for effectiveness and necessity.

Efforts to prevent disease and maintain animal health and welfare should continuously be in place to reduce the need for routinely administered antibiotics.[21] In other words, hygiene, disinfection, bio-security measures, nutrition, cleaning practices, enhanced animal observation, changes in how much time a pen stays open after it has been cleaned, animal density, vaccinations and environmental changes all should be considered before antibiotics are administered. Veterinarians, together with farmers and ranchers, should be jointly responsible for the health of animals on a farm. It is not enough that veterinarians be involved with the mixing of antibiotics at the feed mill or at production company headquarters; they must regularly visit the animals and establish a proper veterinary-client-patient relationship. To help increase the number of large animal veterinarians available to do such work, Congress could consider legislation to incentivize entry into this field.

*The search for solutions:* As a veterinarian, when I look at antibiotic use in food animal production, I am dismayed. It is clear to me that the industry has become too reliant on antibiotics. Today, these life-saving drugs can mask poor animal husbandry practices that lead to diseases that otherwise might not occur. An animal production system that requires regular antibiotic inputs to keep the animals from becoming sick is a flawed system. We have long recognized that routine use of antibiotics in humans leads to antibiotic resistance. We do not try to prevent outbreaks of human diseases using population scale antibiotic treatment except in extremely rare circumstances. Instead, we control infections using vaccination, hygiene and other public health interventions. Yet, we have largely ignored these principles in modern food animal production and enabled a system that relies too heavily on antibiotics to do what good animal husbandry could accomplish without putting human health at risk.

Mr. Chairman, the Pew Campaign on Human Health and Industrial Farming was founded on the recommendations of a blue ribbon commission that cited the routine, non-therapeutic use of antibiotics on industrial farms as the number one public health problem created by these large operations. The Pew Commission on Industrial Farm Animal Production acknowledged that food animals will need to be produced in large-scale operations in order to feed Americans and others in the world as well as compete in the global marketplace. But it stated the current system utilizing routine low levels of antibiotics presented an unacceptable level of threat to public health and damage to the environment.

To that end, I have just returned from a week-long fact-finding mission to Denmark to discover how they managed to successfully ban the nontherapeutic use of antibiotics in food producing animals in an industrial farm setting. Denmark is one of the world's largest exporters of pork. Danish food animal production is industrialized and highly intensive.

Recognizing the potential for a health crisis, Denmark stopped the administration of antibiotics used for growth promotion in broiler chickens and adult swine (finishers) in 1998 and in young swine in 1999. Today in Denmark, all uses of antibiotics in food animal production must be accompanied by a prescription in a valid veterinarian-client-patient relationship and veterinarians cannot profit from the sale of antibiotics. In addition, farmers, veterinarians and pharmacies must report the use and sale of antibiotics. Although the U.S. food animal production and animal drug industries often claim that the ban was costly and ineffective, the World Health Organization found that the Danish ban reduced human health risk without significantly harming animal health or farmers' incomes.[22] In fact, Danish government and industry data show that livestock and poultry production has increased since the ban, while antibiotic resistance has declined on farms and in meat.[23]

I saw first-hand how Denmark has learned to successfully raise animals using antibiotics only when prescribed by a veterinarian. On my trip, I had a chance to visit an industrial swine farm and interview the farmer and his veterinarian, tour the largest slaughter facility in Denmark, discuss genetic improvements in swine and talk to a veterinarian from the Ministry of Food, Agriculture and Fisheries about the government's antibiotic use tracking system. I also had an opportunity to hear what researchers at both the Danish Technical University and the non-government affiliated Pig Research Center are doing on behalf of farmers. They focus on maximizing meat production without using nontherapeutic antibiotics, while continuing to improve the welfare of the animals and meet strict regulations within Denmark and the European Union. The trip was very informative and everyone was very forthcoming. The people I met extended an open invitation to any group that would like to learn for themselves what Denmark has done, what has worked, what has not worked and what they see as the future of Danish food animal production.

In human medicine there are several successful programs in this country that promote the wise use of antibiotics; plus antibiotics are available by prescription only. For example, CDC′s educational campaign, "Get Smart: Know When Antibiotics Work," teaches both the provider and the patient when and how antibiotics should be used. Data from the CDC's *National Ambulatory Medical Care Survey* confirm the campaign′s impact on reducing antibiotic use for acute respiratory tract infections among both children and adults. The survey showed a 20 percent decrease in prescribing for upper respiratory infections and a 13 percent decrease in prescribing overall for all office visits.[24]

As Dr. Sharfstein's testimony today noted, FDA just last month acknowledged the problem of overuse of antibiotics in industrial farming as an urgent public health issue. Over the past 30 years, FDA has sporadically proposed methods to curtail the overuse of life-saving antibiotics in food animal production. And for more than 30 years, opponents have managed to block progress, while antibiotics become less and less effective in saving lives. The newly released FDA draft guidelines for antibiotic use correctly calls for eliminating the use of antibiotics for growth promotion and feed efficiency, which the FDA deems non-judicious. The agency's call for "judicious" use in preventing sickness suggests several principles for evaluating the appropriateness of such uses.[25]

While the draft guidelines are a welcome first step, agribusiness could continue to feed antibiotics to entire flocks or herds to prevent illnesses they may never encounter. This approach to prevention is not allowed in human medicine and it should not be allowed in animals. The draft guidelines are only voluntary and the agency has not indicated its plans to proceed with enforceable requirements. FDA must develop effective, mandatory solutions to the threat of antibiotic resistance to human and animal health. The Pew Charitable Trusts is joined by the leading health and medical organizations in this country in asking the agency to move expeditiously toward the issuance of regulations that will control the widespread use of antibiotics on industrial farms. Unfortunately, regulatory action has been a slow and arduous process, particularly in an atmosphere of industry resistance.

In the meantime, Congress must not wait for FDA. Lawmakers should take swift action to pass the Preservation of Antibiotics for Medical Treatment Act (PAMTA, H.R. 1549). This legislation would disallow the routine use of seven classes of antibiotics vitally important to human health in food animal production unless animals or herds have been exposed to disease or unless drug companies can show with reasonable certainty that their use does not harm human health through antibiotic resistance.

PAMTA would continue to allow the use of antibiotics not deemed critically important for human use to be sold over the counter to farmers and ranchers as needed. This means drugs such as ionophores could still be used in food animal production, because they are not related to drugs used in human medicine and at this point, we believe, do not pose a risk to human health from antibiotic resistance. PAMTA would **not** bar the use of antibiotics for treatment of sick animals.

There is general agreement that antibiotics have a place in animal production. PAMTA does not challenge that notion. The bill would still allow veterinarians to prescribe antibiotics to treat disease while minimizing the reservoir of antibiotic resistant bacteria. This is a solution that works well for human and animal health.

As a member of the American Veterinary Medical Association (AVMA), I am disappointed in the stance that AVMA has taken to oppose PAMTA. Ironically, PAMTA is a pro-veterinarian bill designed to restore the veterinary-client-patient relationship between food animals and medical care. There are many veterinarians in the AVMA who do not share the official viewpoint of the AVMA on PAMTA. The leading medical and public health organizations in the U.S. including the American Medical Association, American Academy of Pediatrics, American Nurses Association and the Infectious Diseases Society of America have all independently called for strictly limiting antibiotic resistance by curbing the amount of drugs fed to food animals. In addition, these groups all endorse PAMTA.

The U.S. has a long, proud history of helping farmers and ranchers and maintaining our top place in the global food market. It is clear that antimicrobial resistance from our overuse of antibiotics in food animals has reached a crisis point. My experience in Kansas and my animal and human health expertise lead me to be confident that American farmers and ranchers along with our best scientists can find solutions. Congress can take a big step toward reducing overuse and protecting life-saving antibiotics by moving forward with PAMTA. Every day that we delay implementing effective and unambiguous legislation to curtail the overuse of antibiotics in food animal production, the risks to the American people increase.

Thank you for the opportunity to testify on this very important issue. I am happy to answer any questions you may have.

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# Antibiotic Resistance and Food Animal Production: a Bibliography of Scientific Studies (1969-2010)

This bibliography lists the latest published scientific and economic literature concerning the contribution of routine antibiotic use in food animals to the growing public health crisis of human antibiotic resistance. Research on how antibiotic use in food animal production contributes to the growing health crisis of antibiotic resistance dates back more than 30 years. As Dr. Frederick J. Angulo, Acting Associate Director of Science in CDC's National Center for Environmental Health and the Agency for Toxic Substances and Disease, said in a August 1, 2009, news article in the *Journal of the American Veterinary Medical Association*:

> "There is scientific consensus that antibiotic use in food animals contributes to resistance in humans. And there's increasing evidence that such resistance results in adverse human health consequences at the population level. Antibiotics are a finite and precious resource, and we need to promote prudent and judicious antibiotic use."

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## ANTIBIOTIC RESISTANCE IN ANIMAL AGRICULTURE

*The impacts of antibiotic resistance in animal agriculture on livestock, the environment and the spreading of infectious diseases.*

**Joint Committee on the use of antibiotics in animal husbandry and veterinary medicine ("Swann Report").** M.M. Swann, et al. Cmnd. 4190. London: Her Majesty's Stationery Office, 1969.

> **Summary:** Reports on the status of antibiotic use in man and animals. Outlines the uses and amounts consumed for both. Reviews the reasons for which antibiotics are administered to food animals, including disease prevention, use in growth promotion, stress reduction and therapy. States that there are possible dangers to the human population stemming from the administration of antibiotics to animals, such as the rise of antibiotic-resistant strains of bacteria in animals that could cause disease in humans. The resulting infection could then be difficult to treat due to the null effect of antibiotics. Other dangers include the transmission of resistance determinants from animal strains to human strains of bacteria. It is known that such transfers take place and the fear is that resistance may be transferred to normal bacteria that inhabit the human bowel and/or to pathogens that may then cause disease. Discusses the prevalence of multiple antibiotic-resistant strains of bacteria and how they may arise. States that even though there are multiple antibiotics available for treatment of certain diseases, those reserved as a drug of choice may have a number of advantages over alternative treatment. Strains with multidrug resistance pose a greater threat in that the only effective drugs left for treatment in humans may be unsuitable because of toxicity or allergy. These infections are likely to arise where humans and animals share a pathogen such as *Salmonella*and the administration of antimicrobials to animals no doubt encourages the prevalence of resistance in these strains. Concludes that the use of antimicrobials in food animal production, especially when used in growth promotion, is of great concern and that limiting factors should be put in place to secure the use of antibiotics of greatest importance in human administration for therapeutic uses only and in some cases excluded from animal use altogether.

**Changes in intestinal flora of farm personnel after introduction of a tetracycline-supplemented feed on a farm.** S.B. Levy, G.B. Fitzgerald and A.B. Macone. *New England Journal of Medicine*, 1976. 295(11): 583-588.

> **Summary:** Reports a study to determine if giving animals antibiotics in feed caused changes in intestinal bacterial flora and if workers and neighbors of the farm were affected. Chickens were screened for bacteria before and after a diet that included tetracycline-supplemented feed. Resistance to tetracycline changed dramatically within 36 to 48 hours of changing the diet of the animals. Within two weeks, 90 percent of the chickens were found to excrete essentially all tetracycline-resistant organisms. Within five to six months, there was a large increase in tetracycline-resistant bacteria in farm dwellers while the neighbors showed no change in bacterial count.

**An epidemic of resistant *Salmonella* in a nursery: Animal-to-human spread.** R.W. Lyons, C.L Samples, H.N. DeSilva, K.A. Ross, E.M. Julian and P.J. Checko. *Journal of the American Medical Association*, 1980. 243(6): 546-547.

> **Summary:** Studies the case of a pregnant woman, infected with *Salmonella heidelberg*, who worked on her father's farm until four days before delivery. Her baby subsequently developed mild diarrhea, as did two others sharing the hospital nursery. *Salmonella heidelberg* was isolated from each and in all cases was resistant to chloramphenicol, sulfamethoxazole and tetracycline.

The strain was presumed to originate from a herd of infected dairy cows at the woman's father's farm as those bacteria showed the same resistance pattern as did those collected from the father.

**Emergence of multidrug-resistant *Salmonella enterica* serotype Typhimurium DT104 infections in the United States.** M.K. Glynn, C. Bopp, W. Dewitt, P. Dabney, M. Mokhtar and F.J. Angulo. *New England Journal of Medicine,* 1998. 338(19): 1333-1338.

**Summary:** Reviews *Salmonella* data collected by local and state health departments and public health laboratories between 1979 and 1996. Finds that a rapid increase of multidrug-resistant *Salmonella enterica* serotype typhimurium (DT104), a strain widely distributed in food animals and known to cause disease in humans, occurred in this period. The percentage rose from 0.6 percent in 1979–1980 to 34 percent in 1996. Concludes that more prudent use of antibiotics on farms is necessary to reduce the dissemination of multidrug-resistant *Salmonella* and emergence of further resistant strains.

**Epidemiologic aspects, control, and importance of multiple-drug resistant *Salmonella* typhimurium DT104 in the United States.** J.E. Akkina, A.T. Hogue, F.J. Angulo, R. Johnson, K.E. Petersen, P.K. Saini, P.J. Fedorka-Cray and W.D. Schlosser. *Journal of the American Veterinary Medical Association,* 1999. 214(6): 790-798.

**Summary:** Studies an animal strain of *Salmonella* and its prevalence of infection in humans. States that multidrug-resistant *Salmonella* DT104 is the second-most-prevalent *Salmonella* organism isolated from humans in England and Wales in the time frame of this study. Gives numerous examples of outbreaks in the U.S., most of which are traced to milk. Cattle, along with pigs, sheep, chickens, turkeys and several other animals, are known carriers of this strain.

**Transfer of antibiotic resistant bacteria from animals to man.** H.C. Wegener, F.M. Aarestrup, P. Gerner-Smidt and F. Bager. *Acta Veterinaria Scandinavica Supplementum*, 1999. 92: 51-57.

**Summary:** Describes zoonotic bacterial infections and their treatment. States that most *Salmonella, campylobacter, yersinia* and entero-haemorrhagic *E. coli* (EHEC) infections do not require antibiotic therapy, but in some cases these tools provide life-saving cures. Increasing levels of resistance in these bacteria, especially fluoroquinolone resistance, give rise for concern when it comes to human infections. Calls for infection control at the herd level and the need for prudent use of antibiotics in food animals.

**Ceftriaxone-resistant *Salmonella* infection acquired by a child from cattle.** P. Fey, T.J. Safranek, M.E. Rupp, E.F. Dunne, E. Ribot, P.C. Iwen, P.A. Bradford, F.J. Angulo and S.H. Hinrichs. *New England Journal of Medicine,* 2000. 342: 1242-1249.

**Summary:** Reports the case of a 12-year-old boy who lived on a farm in Nebraska and was infected with a ceftriaxone-resistant strain of *Salmonella enterica* serotype typhimurium that was traced to his father's herd of cattle using molecular techniques. States that this finding adds to the growing body of evidence suggesting that the use of antibiotics in livestock is the prominent source of resistance to these agents in *Salmonella* infection.

**Appropriate regulation of antibiotics in livestock feed.** R.L. Goforth and C.R. Goforth. *Boston College Environmental Affairs Law Review*, 2000. 28(1): 39-77.

**Summary:** Reviews nontherapeutic uses of antimicrobials in food animals and their impact on human health. States that this practice is creating possibly irreversible effects on the viability of antibiotics used to treat human disease. Concludes that despite short-term economic benefits associated with the widespread use of antibiotics in agriculture, the risk to human health justifies a change in policy.

**Antibiotic resistance in *Campylobacter* strains isolated from animals, foods and humans in Spain in 1997–1998.** Y. Saenz, M. Zarazaga, M. Lantero, M.J. Gastaneres, F. Baquero and C. Torres. *Antimicrobial Agents and Chemotherapy,* 2000. 44(2): 267-271.

**Summary:** Studies *Campylobacter* isolated from foods, animals and humans. Finds that a high percentage of *Campylobacter jejuni* contaminates food (54.4 percent), broilers (81 percent) and pigs (88.9 percent). Isolates collected from broilers and pigs showed a 99 percent resistance rate to ciprofloxacin, with only a slightly lower number of human isolates (72 percent) also resistant. High resistance percentages to ampicillin, erythromycin, gentamicin and amikacin also were detected for *C. coli* isolated from these sources. Concludes that "more restrictive policies on the use of antibiotics in animals may result in an improvement of the current situation in the medium term."

**The effect of banning avoparcin on VRE carriage in The Netherlands.** A.E. van den Bogaard, N. Bruinsma and E.E. Stobberingh. *Journal of Antimicrobial Chemotherapy*, 2000. 46: 146-148.

**Summary:** Discusses the removal of avoparcin, an antimicrobial similar to vancomycin, from commercial food animal production in several settings. Sweden, which banned the use of antibiotics as growth promoters in 1986, has not reported any vancomycin-resistant *Enterococci* (VRE). This example strongly suggests that the removal of selective pressure will remove VRE from the human population over time. Denmark also banned the use of avoparcin in 1995 and saw the prevalence of poultry-isolated cases of VRE drop from greater than 80 percent in 1995 to less than 5 percent in 1998.

**Epidemiology of resistance to antibiotics: Links between animals and humans.** A. Van der Bogaard and E.E. Stobberingh. *International Journal of Antimicrobial Agents,* 2000. 14: 327-335.

**Summary:** Discusses the ban on avoparcin in food animals in the European Union and resulting significant decreases in resistance to vancomycin (a related drug) in intestinal *Enterococci* bacteria in animals and humans. States that resistant bacteria from animals can infect or reach the human population by direct contact and via food products of animal origin. Shows evidence for transfer of resistant genes between bacteria in humans and animals and recommends reducing the amount of antibiotics used in food animals in order to protect public health and safeguard the efficacy of antibiotics in veterinary medicine.

**Quinolone and macrolide resistance in *Campylobacter jejuni* and *C. coli*: Resistance mechanisms and trends in human isolates.** J. Engberg, F.M. Aarestrup, D.E. Taylor, P.Gerner-Smidt and I. Nachamkin. *Emerging Infectious Diseases*, 2001. 7(1):24-34.

**Summary:** Reviews the increasing resistance of *Campylobacter* strains to macrolide and quinolone antibiotics in human clinical isolates with respect to the use of these agents in food animals. Data suggest that while erythromycin and other macrolides should continue to be the antibiotics of choice in most regions, fluoroquinolones may be of limited use in many areas as the overuse of enrofloxacin and other drugs in food animals has caused a sharp upswing in the resistance of *Campylobacter* to these antibiotics.

**The need to improve antimicrobial use in agriculture: Ecological and human health consequences.** Alliance for the Prudent Use of Antibiotics. *Clinical Infectious Diseases*, 2002 supplement. 34 (S3): S71-144.

> **Summary:** Reviews more than 500 studies relating to agricultural uses of antibiotics and concludes that "elimination of nontherapeutic use of antimicrobials in food animals and agriculture will lower the burden of antimicrobial resistance."

**Potential mechanisms of increased disease in humans from antimicrobial resistance in food animals.** M. Barza. *Clinical Infectious Diseases*, 2002. 34 (Suppl 3): S123-125.

> **Summary:** Summarizes five potential mechanisms by which antimicrobial resistance may adversely affect human health. Two of the five relate to antimicrobial use in animals: (1) that resistant pathogens acquired by animals as the result of treatment with antibiotics transmit these pathogens through the food chain; and (2) that commensal flora of animals may acquire resistance traits from the previous pool of resistant pathogens, which then may be passed to human commensals and/or pathogens through the food chain.

**Antimicrobial residues in animal waste and water resources proximal to large-scale swine and poultry feeding operations.** E.R. Campagnolo, K.R. Johnson, A. Karpati, C.S. Rubin, D.W. Kolpin, M.T. Meyer, J.E. Estaban, R.W. Currier, K. Smith, K.M. Thu and M. McGeehin. *The Science of the Total Environment*, 2002. 299: 89-95.

> **Summary:** Reports on data from numerous antimicrobial residues collected from animal wastes, surface water and groundwater proximal to large-scale swine and poultry operations. Data indicate that animal waste applied as fertilizer to the land may serve as a contaminating source of antimicrobial residues for the environment as a detectable level of antimicrobial compounds was found in waste-storage lagoons and surface and groundwater proximal to these operations.

**Antimicrobial use and resistance in animals.** S.A. McEwen, P.J. Fedorka-Cray. *Clinical Infectious Diseases*, 2002. 34 (Suppl 3): S93-106.

> **Summary:** Describes antibiotic use in each animal class. Discusses a 1999 report on the economic effects of banning subtherapeutic antibiotic use in the U.S. Concludes that meat producers following good management practices would not be adversely affected by such a ban. Reviews antimicrobial-resistance-monitoring programs in bacteria of animal origin and the techniques involved. States alternatives to using antibiotics in food animals, such as providing good sanitation, air temperature, and clean water, as well as vaccine use and development and use of probiotics that consist of live, beneficial bacteria.

**Emergence, spread and environmental effect of antimicrobial resistance: How use of an antimicrobial anywhere can increase resistance to any antimicrobial anywhere else.** T.F. O'Brien. *Clinical Infectious Diseases*, 2002. 34(Suppl 3): S78-84.

> **Summary:** Discusses how a bacterial community responds to antimicrobial use by obtaining resistance genes as well as how these genes are spread around the globe and between different bacterial populations. States that in Europe a ban of avoparcin, an antibiotic similar to vancomycin, was implemented in 1997 because of rising concerns that strains of vancomycin-resistant *Enterococci* were being used for growth promotion.

**Generally overlooked fundamentals of bacterial genetics and ecology.** A.O. Summers. *Clinical Infectious Diseases*, 2002. 34 (Suppl 3): S85-92.

**Summary:** Reviews how treatment with any given antibiotic may result in resistance to several antibiotics because of the ability of bacteria to obtain genetic elements that code for multidrug resistance. States that the exchange of bacteria between a host and its environment is a continual processand that selective pressure applied to any part of the ecosystem will result in a highly resistant bacterial population. Also states that once resistance is acquired it will be hard to reverse because of molecular mechanisms inherent in bacteria that ensure future generations hold on to resistance characteristics.

**Human diseases caused by foodborne pathogens of animal origin.** M.N. Swartz. *Clinical Infectious Diseases*, 2002. 34 (Suppl 3): S111-122.

**Summary:** Evaluates the likelihood that emergence of several resistant strains of bacteria occurred first in animals rather than humans. Reviews studies that correlate antimicrobial use on farms to the occurrence of colonization and infection of farm workers and residents of the surrounding communities. Discusses the trend in antibiotic resistance in commensal microorganisms and their opportunistic infection of hospitalized patients.

**Antimicrobial resistance in livestock.** B. Catry, H. Laevens, L.A. Devriese, G. Opsomer and A. Kruif. *Journal of Veterinary Pharmacology and Therapeutics,* 2003. 26: 81-93.

**Summary:** Reviews resistance in animals from a veterinary perspective. Notes that resistance could result in economic losses and animal welfare problems for livestock producers and that "the resistance level in a population is directly related to amount of antimicrobial drugs used." States that commensal bacteria in healthy animals fed or administered antibiotics contain resistance genes that if ingested by humans could colonize the gut and transfer these genes to pathogenic bacteria. This transfer would result in treatment difficulty because of antibiotic resistance.

**Emergence of multidrug-resistant *Salmonella enterica* Serotype Newport infections resistant to expanded-spectrum cephalosporins in the United States.** A. Gupta, et al. *Journal of Infectious Diseases,* 2003. 188: 1707-1716.

**Summary:** Discusses the emergence of new strains of multidrug-resistant *Salmonella* in New England. Reports that isolates of Newport-MDRAmpC among *Salmonella* serotype Newport from humans rose from 0 percent in 1998 to 53 percent in 2001. This strain shows resistance to amoxicillin/clavulanic acid, cephalothin, cefoxitin and ceftiofur. Concludes that the use of antimicrobial agents in livestock is linked to the emergence of antimicrobial-resistant nontyphoidal *Salmonella* and that the emergence of Newport-MDRAmpC strains in humans has coincided with the same infections in cattle.

**Evidence of an association between use of anti-microbial agents in food animals and antimicrobial resistance among bacteria isolated from humans and the human health consequences of such resistance.** F.J. Angulo, V.N. Nargund and T.C. Chiller. *Journal of Veterinary Medicine,* 2004. 51: 374-379.

**Summary:** Reviews antimicrobial-resistant infections occurring in humans as a result of antibiotic use in food animal production. States that "a review of outbreaks of *Salmonella* infections indicated that outbreaks were more likely to have a food animal source than outbreaks caused by anti-microbial-susceptible *Salmonella.*" Reports that the human health consequences resulting from bacterial resistance include infections caused by resistant pathogens, an increase in treatment failures and increased severity of disease.

**Nontherapeutic use of antimicrobial agents in animal agriculture: Implications for pediatrics.** K.M. Shea. *Pediatrics,* 2004. 114(3): 862-868.

**Summary:** Examines how antimicrobials are used in food animal production and how this practice could contribute to resistance in humans. Notes that children are at greater risk from resistant infections than the general population.

**Antibiotic use in agriculture and its impact on the terrestrial environment.** K. Kumar, S.C. Gupta, Y. Chander and A.K. Singh. *Advances in Agronomy*, 2005. 87: 1-54.

**Summary:** Discusses the impact of antibiotic use on disease treatment and growth promotion in animals. States that overuse of antibiotics results in the excretion of drugs that are not absorbed in the animal and that the resulting manure stock may be spread on fields, altering the soil bacteria and contaminating water sources. Notes that the continued prevalent use of antibiotics in agriculture is increasing the emergence of antibiotic-resistant bacteria both in both clinically relevant strains of pathogens and in normal commensal microorganisms. Concludes that "prudent use of antibiotics to a bare minimum along with alternative methods that minimize development and proliferation of resistant bacteria need investigation."

**Agricultural antibiotics and human health: Does antibiotic use in agriculture have a greater impact than hospital use?** D.L. Smith, J. Dushoff and J.G. Morris, Jr. *PLoS Medicine,* 2005. 2(8): 731-735.

**Summary:** Reviews the emergence and spread of antibiotic-resistant bacteria and notes that mathematical models can help with understanding underlying mechanisms and guiding policy responses. Agricultural antibiotic use may generate novel types of antibiotic-resistant bacteria that spread to humans; models can help estimate how much additional disease has been caused by agricultural antibiotic use. Depending on the assumptions used, the model suggests that transmission from agriculture can have a greater impact than hospital transmission on human populations.

**The potential role of concentrated animal feeding operations in infectious disease epidemics and antibiotic resistance.** M.J. Gilchrist, C. Greko, D.B. Wallinga, G.W. Beran, D.R. Riley and P.S. Thorne. *Environmental Health Perspectives*, 2007. 115(2): 313-316.

**Summary:** Reports the recommendations of a working group that was part of the 2005 *"Conference on Environmental Health Impacts of Concentrated Animal Feeding Operations: Anticipating Hazards – Searching for Solutions."* Recommendations include the following: discontinue nontherapeutic use of antibiotics as growth promoters; establish nationwide surveillance programs to fully assess the contribution of antibiotic use in livestock production to the creation of ecological reservoirs of resistance or the transmission of that resistance to humans; identify resistant strains; and establish minimum separation distances for swine and poultry facilities to reduce the risk of influenza outbreaks and municipal-style waste treatment to limit microbial and nutrient contamination of surface and groundwater.

**Fluoroquinolone-resistant *Campylobacter* species and the withdrawal of fluoroquinolones from use in poultry: A public health success story.** J.M. Nelson, T.M. Chiller, J.H. Powers and F.J. Angulo. *Clinical Infectious Diseases,* 2007. 44: 977-980.

**Summary:** Reviews fluoroquinolone use and the resulting effect of resistance occurring in the *Campylobacter* that followed the withdrawal of enrofloxacin from use in treating poultry. States that 13 percent of all resistant infections occur from travel abroad, showing that resistance is a global threat and that U.S. regulatory actions are not effective internationally. Concludes that "judicious use of antimicrobial agents should be stressed to preserve the efficacy of these important chemotherapeutic agents."

**Environmental health impacts of concentrated animal feeding operations: Anticipating hazards—searching for solutions.** P.S. Thorne. *Environmental Health Perspective,* 2007. 115: 296-297.

**Summary:** Outlines potential risks to human health from concentrated animal feeding operations (CAFOs) and the research needed to better understand the impact of these operations on public health. Examples of policy change include establishment of a requirement for minimum separation distances, use of solid-waste storage tanks to eliminate the possibility of microbial contamination spreading to water sources and provision of clean water sources for drinking. Expresses concerns over air quality and the need for better surveillance in this area. Expresses a need to phase out the use of antimicrobial agents as growth promotants.

**Associations between antimicrobial resistance genes in fecal generic *Escherichia coli* isolates from cow-calf herds in western Canada.** S.P. Gow, C.L. Waldner, J. Harel and P. Boerlin. *Applied and Environmental Microbiology,* 2008. 74(12): 3658-3666.

**Summary:** Studies antimicrobial-resistance gene distribution among cow-calf herds in western Canada. Finds that 65 percent of the 207 examined isolates of *E. coli* were resistant to at least one antimicrobial. Several patterns emerged from this research, suggesting that when a bacterium acquires resistance to one antimicrobial it is likely to become resistant to others because of the transfer of mobile genetic elements that harbor regions of multiple drug resistance. This suggests that even with careful restriction of antimicrobial use on farms, bacteria may still pick up resistance unrelated to the antimicrobials being used.

**Industrial food animal production, antimicrobial resistance, and human health.** E.K. Silbergeld, J. Graham and L.B. Price. *Annual Review of Public Health,* 2008. 29: 151-169.

**Summary:** Reviews the use of antimicrobials in agriculture and presents evidence for resistance stemming from their use in food animals. States that agricultural use of antibiotics can significantly shorten the useful life of these drugs, which are also used to treat disease in humans and animals. Suggests that estimates of nontherapeutic antibiotic use in agriculture fall between 60 percent and 80 percent of total antimicrobial production in the U.S. Concludes that "the use of antimicrobials for nontherapeutic purposes in agriculture is a major factor driving the emergence of antimicrobial resistance globally," and that "prudent public health policy thus indicates that nontherapeutic uses of antimicrobials in food animal production should stop."

**Effect of subtherapeutic administration of antibiotics on the prevalence of antibiotic-resistant *Escherichia coli* bacteria in feedlot cattle.** T.W. Alexander, L.J. Yanke, E. Topp, M.E. Olson, R.R. Read, D.W. Morck, T.A. McAllister. *Applied and Environmental Microbiology,* 2008. 74(14): 4405-4416.

**Summary:** A study of *E. coli* resistance in feedlot cattle when they were administered a sub-therapeutic level of antibiotics. Cattle previously not treated with antibiotics were brought to a research feedlot where they were divided into groups each receiving a different regimen of sub-therapeutic antibiotics along with one group as a control not being treated. Cattle were fed two different diets during their treatments, one silage based diet and another grain based. Cattle tested before entering the feedlot (before starting sub-therapeutic treatment) were colonized with *E. coli* resistant to tetracycline (TET) at a rate greater than 40 percent, suggesting a colonization of TET resistant *E. coli* from birth (i.e. there is a high population of *E. coli* in circulation with TET resistance). Additionally the group fed chlortetracycline plus sulfamethazine (TET-SUL) showed an increased rate of TET resistance. A grain-based diet also appeared to increase not only the finding of *E. coli* but also increased the rate of finding TET resistant *E. coli*. Noted is that when antibiotic treatment was stopped for a period of about one to two months during each diet there was not a significant decline in the shedding of resistant *E. coli* except in the TET-SUL group where a slight decline was observed. However, upon starting treatment again the decline was reversed and prevalence of resistance continued to climb. The authors do note that in previous studies a decline in resistance has been shown when antibiotics (selective pressures) were removed from diets of animals, but this may sometimes take years to see a marked decrease. In summary feeding of certain diets and addition of certain sub-therapeutic levels of antibiotics in feed will increase the rate of resistance in *E. coli*.

**The effects of transport and lairage on counts of *Escherichia coli* O157 in the feces and on the hides of individual cattle.** N. Fegan, G. Higgs, L. Duffy and R.S. Barlow. *Foodborne Pathogens and Disease,* 2009. 6(9):1113-1120.

**Summary:** Reports on a study in which *E. coli* O157 rates from feces and from hides of cattle were monitored to determine whether a change occurred during transport from the feedlot to slaughter. Concludes that "transport and lairage did not lead to an increase in the number or isolation rate of *E. coli* O157 from cattle."

**Sublethal antibiotic treatment leads to multidrug resistance via radical-induced mutagenesis.** M.A. Kohanski, M. A. DePristo and J.J. Collins. *Molecular Cell*, 2010. 37:311-320

**Summary:** Looks at mutation rates of *E. coli* exposed to sublethal doses of different antibiotics. Finds that when sublethal doses of antibiotics were given, cell production of radical oxygen species (ROS) occurred, leading to mutations. ROS can damage DNA, causing a mutation in such a way that the cells may acquire resistance to classes of antibiotics different from those with which they are being treated. Gives a clinical example of incomplete treatment with antibiotics (e.g., a missed pill), but one could postulate that in food animal production, where subtherapeutic levels of antibiotics are given for the purpose of growth promotion, this event may also occur.

## SWINE

*Ways in which swine production affects air, water and farm workers.*

**An outbreak of multidrug-resistant, quinolone-resistant *Salmonella enterica* serotype typhimurium DT104.** K. Molbak, D.L. Baggesen, F.M. Aarestrup, J.M. Ebbesen, J. Engberg, K. Frydendahl, P. Gerner-Smidt, A.M. Petersen and H.C. Wegener. *New England Journal of Medicine,* 1999. 341: 1420-1425.

> **Summary:** Reviews a 1998 *Salmonella enterica* serotype typhimurium DT104 outbreak in Denmark. The outbreak had 25 confirmed cases, with 11 patients hospitalized and two deaths. Previous cases were resistant to five antibiotics; however, cases in this outbreak also were resistant to nalidixic acid and had reduced susceptibility to fluoroquinolones. Analysis traced the infection to a swine herd delivered to a slaughterhouse and the resulting retail pork was found to be the common food source.

**Concentrated swine-feeding operations and public health: A review of occupational and community health effects.** D. Cole, L. Todd and S. Wing. *Environmental Health Perspectives,* 2000. 108: 685-699.

> **Summary:** Reviews the effects of industrial farms on community health. States that there are many potential routes of community exposure to industrial farming hazards and that people residing near swine farms may be exposed to these agents through pathways such as airborne contaminants produced by building ventilation fans, soil transport of microbes from land-applied wastes and leaking lagoons that contaminate groundwater. States that more research is needed to determine the far-reaching effects of industrial farms on community health.

**Occurrence and diversity of tetracycline-resistance genes in lagoons and groundwater underlying two swine production facilities.** J.C. Chee-Sanford, R.I. Aminov, I.J. Krapac, N. Garrigues-Jeanjean and R.I. Mackie. *Applied and Environmental Microbiology*, 2001. 67(4): 1494-1502.

> **Summary:** States that 25 percent to 75 percent of antimicrobials administered to food animals are poorly absorbed in the gut and are excreted in feces. These unaltered substances are then applied to land by spreading of manure. Finds that a broad range of tetracycline-resistance genes occurred in two swine-waste lagoons and that upon release into the environment these genes can potentially mobilize and persist. Data suggest that the presence of the resistance genes is due to seepage and movement of groundwater underlying the lagoons and that it may be substantial, as resistance genes were found in a well 250 meters downstream of the lagoon sampled.

**Productivity and economic effects of antibiotics used for growth promotion in U.S. pork production.** G. Y. Miller, K. A. Algozin, P. E. McNamara, E. J. Bush. *Journal of Agricultural and Applied Economics*, 2003. 35(3): 469-482.

> **Summary:** Studies the use of growth promoting antibiotics (GPA) in pork production. Finds that when GPA are removed from production operations that use less than four different rations (feed) there is a net decrease in return at sale of nine percent. However, when farms use greater than four different rations there is an increase in feed conversion without the use of antibiotics. Furthermore, when farms used greater than four different rations and applied GPA, feed conversion decreased. The authors state "our results imply that antibiotics used for growth promotion are of value mainly when four or fewer different rations are used in finishing."

**Antimicrobial resistance in commensal flora of pig farmers.** H. Aubrey-Damon, K. Grenet, P. Sall-Ndiaye, D. Che, E. Cordeiro, M.E. Bougnoux, E. Rigaud, Y. Le Strat, V. Lemanissier, L. Armand-Lefèvre, D. Delzescaux, J.C. Desenclos, M. Liénard and A. Andremont. *Emerging Infectious Diseases,* 2004. 10(5): 873-879.

**Summary:** Compares the carriage rates of antibiotic-resistant bacteria isolated from pig farmers and non-farmers matched for sex, age and county of residence in France. Finds that farmers carry a higher percentage of resistant commensal bacteria than non-farmers. States that the rate of VRE colonization did not differ between farmers and non-farmers and that this finding suggests that the 1997 ban of avoparcin was effective.

**Airborne multidrug-resistant bacteria isolated from a concentrated swine feeding operation.** A. Chapin, A. Rule, K. Gibson, T. Buckley and K. Schwab. *Environmental Health Perspectives*, 2005. 113: 137–142.

**Summary:** Reports the results of studies air samples taken within confined hog operations for antibiotic-resistant bacteria. Ninety-eight percent of bacteria sampled had resistance to at least two antibiotics used in animal production and a greater potential for worker exposure to resistant bacteria, suggesting that exposure to air from swine operations may allow multidrug-resistant bacteria to be transferred from animals to humans. Notes that "these data are especially relevant to the health of swine CAFO [concentrated animal feeding operations] workers, their direct contacts in the community, and possibly nearby neighbors of swine CAFOs."

**Detection and occurrence of antimicrobially resistant *E. coli* in groundwater on or near swine farms in eastern North Carolina.** M.E. Anderson and M.D. Sobsey. *Water Science and Technology*, 2006. 54(3): 211-218.

**Summary:** Compares the extent of groundwater contamination from antibiotic-resistant *E. coli* from industrial swine farms and reference sites. Sixty-eight percent of the *E. coli* from the swine farm sites were resistant to at least one antibiotic, while only one isolate from each of the reference sites showed resistance. Concludes that groundwater on or near swine farms may pose as an environmental pool for antibiotic-resistant *E. coli* and resistance genes.

**The effect of subtherapeutic chlortetracycline on antimicrobial resistance in the fecal flora of swine.** J.A. Funk, J.T. Lejeune, T.E. Wittum and P.J. Rajala-Schultz. *Microbial Drug Resistance*, 2006. 12(3): 210-218.

**Summary:** Studies the occurrence of antimicrobial-resistant *Salmonella* due to the subtherapeutic use of chlortetracycline in the diets of swine. Concludes that "there was a positive association between inclusion of subtherapeutic chlortetracycline in the diet and resistance to multiple antimicrobials."

**Isolation of antibiotic-resistant bacteria from the air plume downwind of a swine confined or concentrated animal feeding operation.** S.G. Gibbs, C.F. Green, P.M. Tarwater, L.C. Mota, K.D. Mena and P.V. Scarpino. *Environmental Health Perspectives,* 2006. 114: 1032–1037.

**Summary:** Studies air samples from upwind, downwind and inside of a confined hog operation. Bacterial samples were tested for antibiotic resistanceand *Staphylococcus aureus was* the dominant species recovered. Samples taken within the barn displayed the highest rate of resistance; samples taken up to 150 meters downwind of the barn showed a higher level of resistance than samples taken upwind. Multiple antibiotic-resistant organisms were also found within and around the barn. Concludes that this increase in antimicrobial resistance could have a negative on the health of people who live around these facilities.

**Community-acquired MRSA and pig-farming.** X.W. Huijsdens, B.J. van Dijke, E. Spalburg, M.G. van Santen-Verheuvel, M.E. Heck, G.N. Pluister, A. Voss, W.J.B. Wannet and A.J. de Neeling. *Annals of Clinical Microbiology and Antimicrobials*, 2006. 5(26).

**Summary:** Reports a mother and baby who were found to be carriers of MRSA. A case study followed, finding that the father was a pig farmer, a screening was done to test coworkers, pigs and family members. Three coworkers, eight of 10 pigs and the father were found to be carriers of MRSA. Molecular characterization of the samples clearly revealed transmission of MRSA from pigs to humans. These findings show clonal spread and transmission of MRSA between humans and pigs in the Netherlands.

**Are swine workers in the United States at increased risk of infection with zoonotic influenza virus?** K.P. Myers, C.W. Olsen, S.F. Setterquist, A.W. Capuano, K.J. Donham, E.L. Thacker, J.A. Merchant and G.C. Gray. *Clinical Infectious Diseases,* 2006. 42: 14-20.

**Summary:** Studies farmers, meat-processing workers, veterinarians and a control group to determine the extent of exposure to pandemic influenza strains originating from pigs. Finds that farmers are at greatest risk and tend to demonstrate a higher titer to both H1N1 and H1N2 swine influenza virus isolates than control subjects do.

**Risk factors for antimicrobial resistance among fecal *Escherichia coli* from residents on forty-three swine farms**. T.H. Akwar, C. Poppe, J. Wilson, R.J. Reid-Smith, M. Dyck, J. Waddington, D. Shang, N. Dassie, and S.A. McEwen. *Microbial Drug Resistance,* 2007. 13(1): 69-76.

**Summary**: Focuses on residents and workers of hog operations that fed antibiotics and those that did not. *E. coli* was obtained from 115 residents and tested for resistance; 25.8 percent of *E. coli* sampled was resistant to at least one antibiotic. Prevalence of resistant bacteria was higher among workers or residents of the farms where antibiotics were fed to hogs. Results indicate that farmers have an increased occupational hazard of exposure to antibiotic-resistant bacteria when antibiotics are fed to animals.

**Monitoring and source tracking of tetracycline resistance genes in lagoons and groundwater adjacent to swine-production facilities over a 3-year period.** S. Koike, I.G. Krapac, H.D. Oliver, A.C. Yannarell, J.C. Chee-Sanford, R.I. Aminov and R.I. Mackie. *Applied and Environmental Microbiology,* 2007. 73(15): 4813-4823.

**Summary:** Studies the dissemination of tetracycline-resistance genes from lagoons into the surrounding environment. DNA was extracted and analyzed by real-time quantitative PCR showing a similarity of 99.8 percent for a selected resistance gene between collected groundwater sample DNA and that of the lagoons. States that this is clear evidence that animal waste seeping from lagoons can affect the environment by spreading resistance genes though groundwater contamination.

**Antibiotic-resistant *Enterococci* and fecal indicators in surface water and groundwater impacted by a concentrated swine feeding operation.** A.R. Sapkota, F.R. Curriero, K.E. Gibson and K.J. Schwab. *Environmental Health Perspectives*, 2007. 115(7): 104-1045.

> **Summary:** Reviews the risks associated with exposure to manure-contaminated water sources by industrial farms. The authors could not obtain specific data on levels of antibiotics in swine feed because it was premixed and delivered by a contracted integrator, which had deemed antibiotic-usage data proprietary information. Reports that elevated levels of fecal indicators and antibiotic-resistant *Enterococci* were detected in water sources situated down-gradient from a swine facility compared with up-gradient surface water and groundwater. Concludes that "the presence of resistant bacteria in both drinking water and surface water sources contaminated by swine farms could contribute to the spread and persistence of both resistant bacteria and antibiotic resistance determinants in humans and the environment."

**Antibiotic resistant bacterial profiles of anaerobic swine-lagoon effluent.** J.P. Brooks and M.R. McLaughlin. *Journal of Environmental Quality,* 2009. 38: 2431-2437.

> **Summary:** Focuses on three types of swine farms—farrowing, nursery and finisher. Antibiotic-resistant bacteria were screened for and isolated from all three types of farm lagoons. States that selective pressures appear to have an effect on the amount of resistant isolates recovered from swine-waste lagoons. Nursery lagoons appeared to be most contaminated, with antibiotic-resistant bacteria most likely due to the elevated use of antibiotics in these operations. Finisher farm lagoons contained the lowest concentration, signaling a lower use of antimicrobials in this environment.

**Prevalence, numbers and characteristics of *Salmonella* spp. on Irish retail pork.** D.M. Prendergast, S.J. Duggan, U. Gonzales-Barron, S. Fanning, F. Butler, M. Cormican and G. Duffy. *International Journal of Food Microbiology,* 2009. 131: 233-239.

> **Summary:** Explores results of a survey of *Salmonella* in samples of pork from butcher shops and retail markets in Ireland and reports that it was found to contaminate 2.6 percent of samples assayed. *S. Typhimurium* was the dominant serotype found, at a rate of 85 percent; it is also one of the most frequently isolated serotypes from humans in the Irish population. Evidence of cross-contamination was found between samples, pointing to the need for good hygiene practices at the retail level.

**Occurrence and persistence of erythromycin resistance genes (*erm*) and tetracycline resistance genes (*tet*) in waste treatment systems on swine farms.** J. Chen, F. C. Michel Jr. S. Sreevatsan, M. Morrison, Z. Yu. *Microbial Ecology,* 2010.

> **Summary:** This study focuses on how to control antibiotic resistance (AR) that is generated by use of antibiotics in confined animal feeding operations (CAFOs). The authors suggest there are two ways to control AR: reduce the use of antimicrobials on farms or find an effective way to minimize AR dissemination off farms by destroying or containing AR on farms. This study focuses on the latter of those two ways and looks to gain perspective on how well swine farms are containing antibiotic resistance by treating animal manure that is produced in CAFOs before it is being disseminated into the environment. Three swine farms were sampled with different types of waste treatment systems. Upon testing in various stages of waste clean up the authors find that "AR arising from swine-feeding operations can survive typical swine waste treatment processes" and call for treatments that are more functional in destroying AR on farms.

## POULTRY

*The effects of poultry production on farm workers, public health and the spread of antibiotic-resistant bacteria.*

**Direct transmission of *Escherichia coli* from poultry to humans.** A.A. Ojenyiyi. *Epidemiology and Infection*, 1989. 103(3): 513-522.

> **Summary:** Compares the resistance traits of *E.coli* collected from free-range poultry with those from poultry in a large-scale commercial facility. Reports that resistance to the antibiotics tested occurred only in those samples collected from birds in a commercial setting. Attendants from the commercial facilities also were found to contain resistant bacteria while samples from villagers in the community were negative. The authors also demonstrated that attendants contract bacteria from birds in their care by conducting a study where they infected birds with a known type of resistant *E. coli* and screened the attendants for the same bacteria.

**Quinolone resistance in *Campylobacter* isolated from man and poultry following the introduction of fluoroquinolones in veterinary medicine.** H.P. Endtz, G.J. Ruijs, B. van Klingeren, W.H. Jansen, T. van der Reyden and R.P. Mouton. *The Journal of Antimicrobial Chemotherapy,* 1991. 27(2): 199-208.

> **Summary:** Reports the results of tests for quinolone resistance in 883 strains of *Campylobacter* bacteria isolated between 1982 and 1989 from human stool and poultry products. *Campylobacter* isolated from poultry increased in resistance from 0 percent to 14 percent in that time, while resistance in human isolates rose from 0 percent to 11 percent. Results suggest that the increase is mainly due to use of enrofloxacin, a fluoroquinolone, in poultry.

**High-frequency recovery of quinupristin-dalfopristin-resistant *Enterococcus faecium* isolates from the poultry-production environment.** J.R. Hayes, A.C. McIntosh, S. Qaiumi, J.A. Johnson, L.L. English, L.E. Carr, D.D. Wagner and S.W. Joseph. *Journal of Clinical Microbiology,* 2001. 39(6): 2298-2299.

> **Summary:** Studies the extent of resistance to quinupristin-dalfopristin, a drug reserved for human use to treat vancomycin-resistant enterococci, in *Enterococcus faecium.* Finds that resistance to this antimicrobial ranged between 51 percent and 78 percent in isolates screened from the food-production environment.

**Antibiotic resistance of faecal *Escherichia coli* in poultry, poultry farmers and poultry slaughterers.** A.E. van den Bogaard, N. London, C. Driessen and E.E. Stobberingh. *Journal of Antimicrobial Chemotherapy,* 2001. 47:763-771.

> **Summary:** Reports a survey of *E. coli* in poultry and workers who were in close contact with animals. Finds that the highest resistance rates were in turkeys, closely followed by broilers. Isolates collected from the laying-hen population were much lower, possibly because of the infrequent use of antibiotics in these animals. In the human population the same results followed, with turkey workers' isolates showing greater resistance than those from broilers or laying-hens. Results also strongly suggest the transmission of resistant clones and resistance plasmids of *E. coli* from broilers and turkeys to humans.

**The dioxin crisis as experiment to determine poultry-related *Campylobacter enteritis*.** A. Vellinga and F. Van Loock. *Emerging Infectious Diseases,* 2002. 8(1): 19-22.

**Summary:** Poultry was withdrawn in Belgium in June 1999 after a contaminant was found in feed. According to a model designed from the sentinel surveillance system, *Campylobacter* infections decreased by 40 percent during that month—from 153 cases per week to 94 cases. States that by using the ban as an epidemiologic tool, the rate of *Campylobacter* infections attributable to poultry was determined to be greater than 40 percent.

**The effect of withdrawing growth promoting antibiotics from broiler chickens: A long-term commercial industry study.** H.M. Engster, D. Marvil, B. Stewart-Brown. *The Journal of Applied Poultry Research,* 2002. 431-436.

**Summary:** A comprehensive study where removal of growth promoting antibiotics (GPA) from broiler chickens was compared with those still receiving GPA. Average reduction of livability was only 0.2 percent on the Delmarva Peninsula (DMV) and 0.14 percent in North Carolina (NC). However, fluctuations were noted in livability from a reduction of 0.5 percent to a positive impact on livability of 0.3 percent. The average reduction in body weight was 0.03 lb on DMV and 0.04 lb in NC but this decline did not start until after the first year of the trial. Feed conversion (weight of food/body weight gain) was not adversely affected in the study for either location. Removal of GPA also resulted in no reports of field outbreaks of disease and total farm condemnations were not affected.

**Fluoroquinolone-resistant *Campylobacter* isolates from conventional and antibiotic-free chicken products.** L.B. Price, E. Johnson, R. Vailes and E. Silbergeld. *Environmental Health Perspectives,* 2005. 113: 557-560.

**Summary:** Concludes that there is no difference in *Campylobacter* contamination between conventionally raised chickens and poultry raised antibiotic-free; however, conventionally raised poultry is more likely to be resistant to antibiotics than chickens raised antibiotic-free. The findings also suggest that fluoroquinolone-resistant isolates of *Campylobacter* may persist after the usage of fluoroquinolones in poultry production has ceased.

**Similarity between human and chicken *Escherichia coli* isolates in relation to ciprofloxacin resistance status.** J.R. Johnson, M.A. Kuskowski, M. Menard, A. Gajewski, M. Xercavins and J. Garau. *The Journal of Infectious Diseases,* 2006. 194(1): 71-78.

**Summary:** Studies the similarities of *E. coli* isolates collected from humans and chickens that were resistant to ciprofloxacin. Finds that resistant *E. coli* in humans appears to have a profile similar to that of resistant *E. coli* collected from chickens, suggesting that the use of antimicrobials in poultry production is leading to resistant *E. coli* that are being transferred to humans, possibly though contaminated meats.

**Use of streptogramin growth promoters in poultry and isolation of streptogramin-resistant *Enterococcus faecium* from humans**. A.L. Kieke, M.A. Borchardt, B.A. Kieke, S.K. Spencer, M.F. Vandermause, K.E. Smith, S.L. Jawahir and E.A. Belongia. *The Journal of Infectious Diseases,* 2006. 194(9): 1200-1208.

**Summary:** Examines virginiamycin use in poultry and its effect on cross-resistance to quinupristin-dalfopristin, a drug also in the streptogramin category that is intended for treating vancomycin-resistant *Enterococcus faecium* infections in humans. The study enrolled patients from hospitals and vegetarians and compared the samples from humans with samples collected from retail poultry meats. Reports that "poultry exposure is associated with a quinupristin-dalfopristin resistance gene and inducible quinupristin-dalfopristin resistance in human fecal *E. faecium.* The continued use of virginiamycin may increase the potential for streptogramin-resistant *E. faecium* infection in humans."

**Subtherapeutic tylosin phosphate in broiler feed affects *Campylobacter* on carcasses during processing.** M.E. Berrang, S.R. Ladely, R.J. Meinersmann and P.J. Fedorka-Cray. *Poultry Science*, 2007. 86:1229-1233.

**Summary:** Studies cross-resistance of tylosin and erythromycin (both macrolide drugs). Erythromycin is often the drug of choice for treating campylobacteriosis, and tylosin is approved at subtherapeutic levels for use in broiler feed for growth promotion. Seventy chicks were divided into two groups, half raised on tylosin, half without. Carcasses of broilers fed tylosin had lower numbers of *Campylobacter,* but all the *Campylobacter* found were resistant to erythromycin. No *Campylobacter* isolated from the control carcasses were resistant. Concludes that application of tylosin phosphate in feed results in lower numbers of *Campylobacter,* but those that remain are resistant to erythromycin.

**Growth promoting antibiotics in food animal production: An economic analysis.** J.P. Graham, J.J. Boland and E. Silbergeld. *Public Health Reports*, 2007. 122:79-87.

**Summary:** Examines the economic effect of removing antibiotics used for growth promotion in broiler chickens using data published by Perdue. Positive production changes were associated with use, but were insufficient to offset the cost of the antibiotics. The net effect of using growth-promoting antibiotics was a lost value of $.0093 per chicken (about 0.45 percent of total cost).

**Development of macrolide-resistant *Campylobacter* in broilers administered subtherapeutic or therapeutic concentrations of tylosin.** S.R. Ladely, M.A. Harrison, P.J. Fedorka-Cray, M.E. Berrang, M.D. Englen and R.J. Meinersmann. *Journal of Food Protection*, 2007. 70(8):1915-1951.

**Summary:** Looks at the impact of antibiotic use on increasing the amount of resistant bacteria in an environment. Poultry were divided into groups of 25 birds: the treatment group was given either therapeutic or subtherapeutic doses of tylosin beginning at two weeks of age while the control group was isolated and not given any antimicrobials. The animals fed subtherapeutic and therapeutic doses of tylosin tested positive for resistant bacteria; no resistant strains were found among the birds that did not get treated with tylosin. The birds treated with subtherapeutic doses of tylosin also showed increased resistance compared with the birds treated with therapeutic doses.

**Elevated risk of carrying gentamicin-resistant *Escherichia coli* among U.S. poultry workers.** L.B. Price, J.P. Graham, L.G. Lackey, A. Roess, R. Vailes and E. Silbergeld. *Environmental Health Perspectives*, 2007. 15(12):1738-1742.

**Summary:** Examines poultry workers and residents on the eastern shore of Maryland and Virginia. Poultry workers had 32 times the odds of being colonized with gentamicin-resistant *E. coli* as community residents; the poultry workers also had an elevated risk of carrying multidrug-resistant *E. coli.* Concludes that "occupational exposure to live animals in the broiler chicken industry may be an important route of entry for antimicrobial-resistant bacteria in to the community."

**Antimicrobial resistance of old and recent *Staphylococcus aureus* isolates from poultry: First detection of livestock-associated methicillin-resistant strain ST398.** M. Nemati, K. Hermans, U. Lipinska, O. Denis, A. Deplano, M. Struelens, L.A. Devriese, F. Pasmans and F. Haesebrouck. *Antimicrobial Agents and Chemotherapy*, 2008. Oct: 3817-3819.

> **Summary:** Compares the resistance profiles of *Staphylococcus aureus* isolates collected from chickens in the 1970s with profiles from healthy chickens in 2006. Finds that resistant levels to eight of the drugs tested were significantly greater in the 2006 samples.

**Food animal transport: A potential source of community exposures to health hazards from industrial farming (CAFOs).** A.M. Rule, S.L. Evans and E.K. Silbergeld. *Journal of Infection and Public Health*, 2008. 1(1): 33-39.

> **Summary:** Compares air samples collected while cars with bacterial-collection equipment were driven behind poultry transport vehicles with background samples taken during normal driving conditions. Twenty-five percent of samples collected while following poultry transport vehicles were resistant at least one antimicrobial, while all background samples were susceptible. Suggests that open-air poultry transport vehicles may play a role in spreading resistant bacteria that originated from the administration of antimicrobials to food animals.

**Relationships between multidrug-resistant *Salmonella enterica* Serovar Schwarzengrund and both broiler chickens and retail chicken meats in Japan.** T. Asai, K. Murakami, M. Ozawa, R. Koike and H. Ishikawa. *Japanese Journal of Infectious Diseases,* 2009. 62: 198-200.

> **Summary:** A *Salmonella* strain that causes invasive salmonellosis in humans was isolated from broiler chickens and retail chicken meats in Japan. Numerous isolates showed multidrug resistance.

**Fate of antimicrobial-resistant *Enterococci* and *Staphylococci* and resistance determinants in stored poultry litter.** J.P. Graham, S.L. Evans, L.B. Price and E.K. Silbergeld. *Environmental Research,* 2009. 109: 682-689.

> **Summary:** Studies the storage of poultry litter and the stability of bacteria and resistance genes during storage. Finds that over a 120-day period, typical storage practices of poultry litter are not sufficient for eliminating drug-resistant *Enterocci* and *Staphylococci,* which may then be delivered to the environment by land application, aerosolization or water contamination during runoff.

**Antibiotic-resistant *Enterococci* and *Staphylococci* isolated from flies collected near confined poultry feeding operations.** J.P. Graham, L.B. Price, S.L. Evans, T.K. Graczyk and E.K. Silbergeld. *Science of the Total Environment,* 2009. 407(8): 2701-2710.

> **Summary:** Investigators collected poultry litter and trapped flies around poultry farms to determine the extent of bacteria present and their resistance-gene profile. Results suggest that flies around poultry operations harbor resistant bacteria in their digestive tracts and exterior surfaces. This could result in human exposure to resistant bacteria that arise from antimicrobial use on poultry farms. Highlights the persistence of resistant genes in the environment and the pool of resistance associated with the use of antibiotics in feed additives.

***Salmonella Heidelberg* Ceftiofur-related resistance in human and retail chicken isolates.** Public Health Agency of Canada. 2009.

**Summary:** In response to public health concerns about the rise of resistance in isolates of *Salmonella* and *E. coli* to ceftiofur, all broiler chicken hatcheries in Québec voluntarily stopped using ceftiofur in February 2005. This publication reports a decrease in the number of ceftiofur-resistant isolates in both chicken and human *S. heidelberg* isolates and in chicken *Escherichia coli* following the voluntary withdrawal of ceftiofur in hatching and day-old chicks in Québec.

**Ceftiofur resistance in *Salmonella enterica* Serovar Heidelberg from chicken meat and humans, Canada.** L. Dutil, R. Irwin, R. Finley, L. King Ng, B. Avery, P. Boerlin, A. Bourgault, L. Cole, D. Daignault, A. Desruisseau, W. Demczuk, L. Hoang, G.B. Horsman, J. Ismail, F. Jamieson, A. Maki, A. Pacagnella and D.R. Pillai. *Emerging Infectious Diseases*, 2010. 16(1): 48-54.

**Summary:** Studies *Salmonella* Heidelberg, a frequently reported cause of infections in North America with sources linked to consumption of poultry, eggs or egg-containing products. Compares resistance rates of *Salmonella* Heidelberg isolates collected from retail chicken to ceftiofur, a third-generation cephalosporin, with rates of human infections that also were resistant to ceftiofur during a period from 2003 to 2008. During this time frame ceftiofur was removed from extralabel use in chicken hatcheries in Québec, resulting in a dramatic decrease in ceftiofur resistance in *Salmonella* Heidelberg and *E. coli* in retail chicken. A similar decrease is shown in resistant human infections of *Salmonella* Heidelberg. Suggests that managing ceftiofur use at the hatchery level may control resistance rates to extended-spectrum cephalosporins. A partial reintroduction of ceftiofur use in hatcheries in 2007 caused a rise in ceftiofur resistance in *E. coli,* but at lower levels than those seen in 2003 to 2004.

**Veterinary pharmaceuticals and antibiotic resistance of Escherichia coli isolates in poultry litter from commercial farms and controlled feeding trials.** V. Furtula, E.G. Farrell, F. Diarrassouba, H. Rempel, J. Pritchard, M.S. Diarra. *Poultry Science*, 2010. 89:180-188.

**Summary**: This study found that there were antimicrobial residues in broiler litter from both a controlled environment, where chickens were fed a diet of feed with additives of bacitracin, chlortetracycline, monensin, narasin, nicarbazin, penicillin, salinomycin and virginiamycin and from commercial farms where the same feed additives were also used. Antimicrobials are not fully absorbed by animals in some cases and will be excreted into the litter leaving a residue of antibiotics that may then be applied to soil for crop fertilization. If application occurs, soil microbes will be subjected to these antibiotic pressures and may develop resistance themselves. There is also evidence for plants to uptake antimicrobial agents and can become a source of exposure to such compounds. *E. coli* isolates were collected from poultry litter from commercial farms and were found to be resistant to at least seven different antibiotics. Isolates from commercial farms showed a higher rate of resistance possibly due to the frequent use of feeds that are available with multiple antibiotics incorporated causing increased resistance. Resistance to such antibiotics as trimethoprim-sulfamethoxazole from isolates collected on commercial farms is of concern as this is a leading treatment of urinary tract infections.

## RETAIL PRODUCTS

*How industrial food animal production affects the food supply.*

**An evaluation of methods to assess the effect of antimicrobial residues on the human gut flora.** D. Corpet. *Veterinary Microbiology*, 1993. 35(3-4):199-212.

> **Summary:** Reviews the effects of antimicrobial residues on the human gut flora and concludes that "most resistant enterobacteria in the human gut of untreated people come from bacterial contamination of raw foods." This assumption stems from a study previously completed by the author in which a sterile diet was given to seven healthy volunteers with an outcome of reduced antibiotic-resistant bacteria in stools.

**Quinoline-resistant *Campylobacter jejuni* infections in Minnesota, 1992–1998.** K.E. Smith, J.M. Besser, C.W. Hedberg, F.T. Leano, J.B. Bender, J.H. Wickland, B.P. Johnson, K.A. Moore and M.T. Osterholm. *New England Journal of Medicine*, 1999. 340(20):1525-1532.

> **Summary:** Reports that ciprofloxacin-resistant *C. jejuni* was isolated from 14 percent of 91 domestic chicken products obtained from retail markets in 1997. The number of quinolone-resistant infections acquired domestically has increased, largely because of the acquisition of resistant strains from poultry. Resulting infections may require additional antimicrobial therapy, as fluoroquinolones such as ciprofloxacin are commonly prescribed for diarrheal illnesses caused by *Campylobacter jejuni*.

**Isolation of antimicrobial-resistant *Escherichia coli* from retail meats purchased in Greater Washington, DC, USA.** C.M. Schroeder, D.G. White, B. Ge, Y. Zhang, P.F. McDermott, S. Ayers, S. Zhao, J. Meng. International Journal of Food Microbiology, 2003. 85: 197-202.

> **Summary:** Retail meat samples were collected and analyzed from the DC area for presence of *E. coli*. Data on resistance to 11 antimicrobials are given with a large portion showing resistance to such antibiotics as tetracycline (59 percent), sulfamethoxazole (45 percent), streptomycin (44 percent), ampicillin (35 percent) and gentamicin (12 percent). The authors conclude that their findings suggest retail meats may often be contaminated with resistant *E. coli*.

**Concurrent quantitation of total *Campylobacter* and total ciprofloxacin-resistant *Campylobacter* loads in rinses from retail raw chicken carcasses from 2001 to 2003 by direct plating at 42 degrees Celsius.** R. Nannapaneni, R. Story, K.C. Wiggins and M.G. Johnson. *Applied and Environmental Microbiology*, 2005. 71(8): 4510-4515.

> **Summary:** Analyzes the total amount of *Campylobacter* present in retail chicken as well as in ciprofloxacin-resistant isolates. Finds that ciprofloxacin-resistant *Campylobacter* persisted throughout the two-and-a-half-year study, showing a reservoir of resistance in the U.S. food market.

**Sulfamethazine uptake by plants from a manure-amended soil.** H. Dolliver, K. Kumar and S. Gupta. *Journal of Environmental Quality*, 2007. 36:1224-1230.

> **Summary:** Studies the uptake of sulfamethazine, an antibiotic extensively used in animal agriculture for therapeutic and subtherapeutic purposes, in corn, lettuce and potatoes when manure-amended soil is used as the growing medium. Following 45 days of growth, all plants tested were contaminated with the antibiotic in varying concentrations.

**Antimicrobial drug-resistant *Escherichia coli* from humans and poultry products, Minnesota and Wisconsin, 2002–2004.** J.R. Johnson, M.R. Sannes, C. Croy, B. Johnston, C. Clabots, M.A. Kuskowski, J. Bender, K.E. Smith, P.L. Winokur and E.A. Belongia. *Emerging Infectious Diseases*, 2007, 13(6): 838-846.

> **Summary:** Studies susceptible and resistant *E. coli* collected from hospital patients, healthy vegetarians and poultry that were raised conventionally and without antibiotics. Suggests that many resistant human isolates may originate from poultry. Isolates from healthy vegetarians also follow this pattern, suggesting that avoidance of poultry consumption does not decrease the possibility of carrying drug-resistant *E. coli* from poultry.

**The isolation of antibiotic-resistant *Salmonella* from retail ground meats.** D.G. White, S. Zhao, R. Sudler, S. Ayers, S, Friedman, S. Chen, P.F. McDermott, S. McDermott, D.D. Wagner and J. Meng. *New England Journal of Medicine*, 2007. 345(16):1147-1154.

> **Summary:** Researchers tested *Salmonella* from samples of ground chicken, pork, beef and turkey purchased at three supermarkets in the Washington, DC, area. Of 200 samples, 41 (20 percent) contained *Salmonella*. Eighty-four percent of those were resistant to at least one antibiotic and 53 percent were resistant to at least three antibiotics. Sixteen percent were resistant to ceftriaxone, the drug of choice for treating salmonellosis in children.

**Resistance in bacteria of the food chain: Epidemiology and control strategies.** F.M. Aarestrup, H.C. Wegener and P. Collignon. *Expert Reviews*, 2008. 6(5): 733-750.

> **Summary:** Reviews bacterial resistance due to the use of antimicrobials in food animals and their transferability to humans in the form of pathogens. States that limiting the selective pressure in food animal production, especially those antibiotics that are critically important to human health, will help control the emergence of resistant bacteria most efficiently.

**Molecular analysis of *Escherichia coli* from retail meats (2002–2004) from the United States National Antimicrobial Resistance Monitoring System.** J.R. Johnson, J.S. McCabe, D.G. White, B. Johnston, M.A. Kuskowski and P. McDermott. *Clinical Infectious Diseases*, 2009. 49: 195-201.

> **Summary:** Researchers screened 287 *E. coli* isolates collected by the National Antimicrobial Resistance Monitoring System (NARMS) for virulence-associated genes. Resistant and susceptible strains differed minimally based on the assessed virulence factors; however, the four meat types screened showed a great variance as chicken and turkey isolates had consistently higher virulence scores than beef and pork samples. These results support the hypothesis that antimicrobial-resistant *E. coli* in retail meats emerge from a host species-specific lineage due to the direct effect of selection pressure from use of antimicrobials or as part of the organisms' adaptations to their respective hosts.

**Transient intestinal carriage after ingestion of antibiotic-resistant *Enterococcus faecium* from chicken and pork.** T.L. Sorensen, M. Blom, D.L. Monnet, N. Frimodt-Moller, R.L. Poulsen and F. Espersen. *New England Journal of Medicine*, 2009. 345(16): 1161-1166.

> **Summary:** Reports on a study designed to test the ability of *Enterococci* from various meat sources to have sustained viability in the human intestine. Twelve volunteers ingested a suspension of *Enterococci* that originated from either a pig or chicken source that was resistant to at least one antibiotic. None of the 12 volunteers was colonized with resistant *Enterococci* at the onset of the experiment; however, eight of the 12 had antibiotic-resistant *Enterococci* isolated at

six days following ingestion, and one had resistant *Enterococci* at 14 days' post ingestion. Concludes that ingestion of resistant *Enterococci* of animal origin leads to detectable concentrations of the same resistant strain in stools for up to 14 days.

**Methicillin-resistant *Staphylococcus aureus* in food products: Cause for concern or complacency?** J. A. J. W. Kluytmans. Clinical Microbiology and Infection, 2010. 16(1): 11-15.

**Summary**: A review on an emerging sequence type of MRSA ST398, which has been isolated from various food animals. A recent study in the U.S. observed a contamination rate of 39.2 percent for *S. aureus* on retail meats and in that group 5 percent was MRSA. Studies abroad have shown rates of MRSA contaminating retail meats as high as 11.9 percent. The author suggests that even though ST398 does not appear to spread easily among humans this assumption needs to be confirmed in well-designed studies. The spread of ST398 from animals to humans needs to be monitored as the potential threat from the retail food reservoir has widespread potential implications on human health.

## MRSA

*The impacts of methicillin-resistant* Staphylococcus aureus *(MRSA) on certain areas across the country, veterinarians, health care employees and farmers.*

**Methicillin-resistant *Staphylococcus aureus* in pig farming.** A. Voss, F. Loeffen, J. Bakker, C. Klaassen and M. Wulf. *Emerging Infectious Diseases*, 2005. 11(12): 1965-1966.

> **Summary:** Examines cases of MRSA colonization resulting from farmers' contact with pigs, how it moved though their families and was transmitted between a hospital patient and nurse. Reports that the frequency of MRSA among the group of regional pig farmers is more than 760 times higher than that among the general Dutch population.

**Methicillin-resistant *Staphylococcus aureus* colonization in veterinary personnel.** B.A. Hanselman, S.A. Kruth, J. Rousseau, D.E. Low, B.A. Willey, A. McGeer and J.S. Weese. *Emerging Infectious Diseases*, 2006. 12(12): 1933-1938.

> **Summary:** Reports a comprehensive evaluation of veterinary personnel for carriage of MRSA. Samples were taken from participants who resided in 19 different countries and rates of colonization were determined. Of the volunteers, 6.5 percent were positive for MRSA; those working with larger animals showed higher carriage rates (15.6 percent).

**Hospitalizations and deaths caused by methicillin-resistant *Staphylococcus* aureus, United States, 1999–2005.** E. Klein, D.L. Smith and R. Laxminarayan. *Emerging Infectious Diseases*, 2007. 13(12): 1840-1846.

> **Summary:** Reports on trends in MRSA infections between 1999 and 2005. The estimated rise in hospitalizations due to *Staphylococcus aureus* infections during this time was 62 percent, while the rate of MRSA infections more than doubled.

**Invasive methicillin-resistant *Staphylococcus aureus* infections in the United States.** R.M. Klevens, M.A. Morrison, J. Nadle, S. Petit, K. Gershman, S. Ray, L.H. Harisson, R. Lynfield, G. Dumyati, J.M. Townes, A.S. Craig, E.R. Zell, G.E. Fosheim, L.K. McDougal, R.B. Carey and S.K. Fridkin. *Journal of the American Medical Association*, 2007. 285(15):1763-1771.

> **Summary:** Finds that MRSA affects certain populations disproportionately, particularly African Americans. After researching invasive MRSA infections reported in hospitals in eight U.S. cities and the state of Connecticut, the authors estimate that in 2005 more than 94,000 cases of such infections occurred, 18,650 of which were fatal.

**Emergence of methicillin-resistant *Staphylococcus aureus* of animal origin in humans.** I. van Loo, X. Huijsdens, E. Tuemersma, A. de Neeling, N. van de Sande-Bruinsma, D. Beaujean, A. Voss and J. Kluytmans. *Emerging Infectious Diseases*, 2007. 13(12):1834-1839.

> **Summary:** Reports that a new type of MRSA from an animal reservoir (pigs in the Netherlands) has recently entered the human population and is now responsible for greater than 20 percent of all MRSA in the Netherlands. As most nontypable MRSA isolates are resistant to doxycycline, the spread of MRSA may be facilitated by the abundant use of tetracyclines in pig and cattle farming.

**Methicillin-resistant *Staphylococcus aureus* ST398 in humans and animals, Central Europe.** W. Witte, B. Strommenger, C. Stanek and C. Cuny. *Emerging Infectious Diseases*, 2007. 13(2): 255-258.

**Summary:** Studies recent human colonization by MRSA ST398, which in previous years had not been seen in humans. Animal-to-human transmission may occur with this strain; for example, a dog being treated for a wound infection transmitted ST398 to the staff of the veterinary practice where the dog was treated. Concludes that "MRSA exhibiting ST398 may colonize and cause infections in humans and in certain animal species such as dogs, horses and pigs."

**Methicillin-resistant *Staphylococcus aureus* colonization in pigs and pig farmers.** T. Khanna, R. Friendship, D. Dewey and J.S. Weese. *Veterinary Microbiology,* 2008. 128:298-303.

**Summary:** This study, the first of MRSA and pig farms in Canada, found that the prevalence of MRSA colonization on pig farms was 45 percent; prevalence in pig farmers was 20 percent. Humans residing on farms where pigs were free of MRSA also tested negative for MRSA. The authors note another study in which MRSA was identified in food products intended for human consumption, but none originated in pigs. This study adds support to the hypothesis that MRSA can be transmitted between pigs and humans.

**Pigs as source of methicillin-resistant *Staphylococcus aureus* CC398 infections in humans, Denmark.** H.C. Lewis, K. Molbak, C. Reese, F.M. Aarestrup, M. Selchau, M. Sorum and R.L. Skov. *Emerging Infectious Diseases*, 2008. 14(9): 1383-1389.

**Summary:** Provides evidence that persons exposed to animals on farms in Denmark, particularly pig farms, have an increased chance of being colonized or infected with MRSA CC398.

**Methicillin-resistant and -susceptible *Staphylococcus aureus* sequence type 398 in pigs and humans.** A.van Belkum, D.C. Melles, J.K. Peeters, W.B. van Leeuwen, E. van Duijkeren, X.W. Huijsdens, E. Spalburg, A.J. de Neeling and H.A. Verbrugh. *Emerging Infectious Diseases*, 2008. 14(3):479-483.

**Summary:** Reports that MRSA ST398, primarily a pathogen of pigs, appears to be quite virulent and can cause bacteremia in humans. States that if MRSA ST398 obtains this pathogenicity, care should be taken not to introduce this strain into humans.

**Transmission of methicillin-resistant *Staphylococcus aureus* strains between different kinds of pig farms.** E. van Duijkeren, R. Ikawaty, M.J. Broekhuizen-Stins, M.D. Jansen, E.C. Spalburg, A.J. de Neeling, J.G. Allaart, A.van Nes, J.A.Wagenaar and A.C. Fluit. *Veterinary Microbiology*, 2008. 126: 383-389.

**Summary:** MRSA strains were found in 23 percent of the farms tested. States that the use of standard antimicrobials "seems to be a risk factor for finding MRSA-positive pigs on a farm. Pig farms on which the pigs were treated with antimicrobials as group medication had a higher risk of being MRSA positive, whereas farms on which antimicrobials were used restrictively had a much lower chance of being MRSA positive."

**Increase in a Dutch hospital of methicillin-resistant *Staphylococcus aureus* related to animal farming.** M.M.L. van Rijen, P.H. Van Keulen and J.A. Kluytmans. *Clinical Infectious Diseases,* 2008. 16:261-263.

**Summary:** Reports on a study 2002–2006 in the Netherlands involving hospital patients who had MRSA. Patients exposed to pigs or veal calves were shown to be at higher risk for MRSA as there was an emergence of nontypable MRSA during this time. Nontypable MRSA is assumed to stem from pigs and calves.

**Methicillin-resistant *Staphylococcus aureus* (MRSA) strain ST398 is present in Midwestern U.S. swine and swine workers.** T.C. Smith, M.J. Male, A.L. Harper, J.S. Kroeger, G.P. Tinkler, E.D. Moritz, A.W. Capuano, L.A. Herwaldt and D.J. Diekema. *PLoS ONE*, 2009. 4(1): e4258.

> **Summary:** Investigates MRSA in the Midwestern U.S. Samples were taken from swine and production workers in two commercial operations. MRSA prevalence was 49 percent in swine and 45 percent in workers. Results show that MRSA is common in swine production in the U.S. and that these animals could be harboring the bacterium.

**Methicillin-resistant *Staphylococcus aureus*: A new zoonotic agent?** B. Springer, U. Orendi, P. Much, G. Hoger, W. Ruppitsch, K. Krziwanek, S. Metz-Gercek and H. Mittermayer. *The Middle European Journal of Medicine*, 2009. 121: 86-90.

> **Summary:** Discusses changes in MRSA over the past decade. Once known almost completely as a hospital pathogen, MRSA is now emerging in the community in persons without hospital-related risk factors. Recent evidence also has shown a link between livestock colonization and MRSA infections in persons working with these animals. Identifies three potential transmission routes of MRSA: from animal origin into the population; human-to-human contact from farm workers to the community; via food or by environmental contamination.

**Methicillin resistant Staphylococcus aurues ST398 in veal calf farming: Human MRSA carriage related with animal antimicrobial usage and farm hygiene.** H. Graveland, J.A. Wagenaar, H. Heesterbeek, D. Mevius, E. van Duijkeren, D. Heederik. *PLoS One*, 2010. 5(6): 1-6.

> **Summary:** Studies MRSA ST398 carriage in veal calves, farmers, their family members and employees. A large sampling size of veal calf farms in the Netherlands was selected at random to be screened for ST398. All participants were given a questionnaire to fill in describing their contact and role on the farm as well as how farm operations were conducted. Samples from both humans and veal calves were cultured and categorized using molecular techniques. The data presented show that direct associations between human and animal carriage of MRSA ST398 exist and that carriage was shown to increase in calves as antibiotic use on the farm increased. Duration of contact to veal calves showed a highly elevated risk of MRSA ST398 carriage in humans and a decrease in MRSA was seen in farms with better hygiene practices (ie cleaning of stables before new claves were brought on the farm). Disinfection was applied in less than 20 percent of the farms in the study and was not associated with prevalence of MRSA carriage in calves. Overall the prevalence of MRSA was 15.9 percent in participants who lived or worked on veal calf farms, which is far greater than the general population carriage rate in the Netherlands estimated to be below 1 percent.

## ANTIMICROBIAL-RESISTANT INFECTIONS

*Infections arising with implications toward the use of antimicrobials in food animal production.*

**Widespread distribution of urinary tract infections caused by a multidrug-resistant *Escherichia coli* clonal group.** A.R. Manges, J.R. Johnson, B. Foxman, T.T. O'Bryan, K.E. Fullerton and L.W. Riley. *New England Journal of Medicine,* 2001. 345(14): 1007-1013.

> **Summary:** Studies urinary tract infections (UTIs) in the U.S. caused by *E. coli* resistant to trimethoprim–sulfamethoxazole as well as other antibiotics. Concludes that UTIs may be caused by contaminated foods, as the outbreaks appear to follow a pattern similar to that of *E. coli* O157 as they spread throughout a community.

**Fluoroquinolone resistance in *Camplyobacter* absent from isolates, Australia.** L. Unicomb, J. Ferguson, T.V. Riley and P. Collignon. *Emerging Infectious Diseases,* 2003. 9(11): 1482-1483.

> **Summary:** Reports on a study of fluoroquinolone resistance in New South Wales, Australia, over a three-year period. Only 12 *Campylobacter* isolates were found to be resistant to fluoroquinolones. Ten of these were related to travel; travel status of the other two is unknown. Australia has never allowed the use of fluoroquinolones in food animal production, a policy that may have impacts on human health for countries with fluoroquinolone-resistant cases of *Campylobacter*.

**Possible animal origin of human-associated, multidrug-resistant, uropathogenic *Escherichia coli*.** M. Ramchandi, et al. *Clinical Infectious Disease,* 2005. 40: 251-257.

> **Summary:** Reviews a collection of 495 animal and environmental *E. coli* isolates collected by the Gastroenteric Disease Center and determines that 26 percent had indistinguishable characteristics from human isolates. Concludes that the data suggest that drug-resistant, uropathogenic, human-associated *E. coli* strains may have an animal origin and that drug-resistant urinary tract infections in humans could be derived from foodborne illnesses.

**The rising influx of multidrug-resistant gram-negative bacilli into a tertiary care hospital**. A.E. Pop-Vicas, E. M. C. D'Agata. *Clinical Infectious Diseases,* 2005. 40: 1792-8.

> **Summary:** Studies multi-drug resistant (MDR) *E. coli*, *Klebsiella* species, *Enterobacter cloacae*, and *Pseudomonas aeruginosa* isolates from patients harboring these bacteria upon entering a hospital in Israel (within 48 hours of admittance). Finds that between 1998 and 2003 the prevalence of MDR isolates of all listed species increased significantly except *Pseudomonas aeruginosa.* Of the 464 isolates collected 12 percent, 35 percent and 53 percent were resistant to 5, 4 and 3 antimicrobial groups, respectively.

**Analysis of a uropathogenic *Escherichia coli* clonal group by multilocus sequence typing.** S.Y. Tartof, O.D. Solberg, A.R. Manges, L.W. Riley. *Journal of Clinical Microbiology*, 2005. 5860-5864.

> **Summary:** Forty-five strains of uropathogenic *E. coli* were analyzed by a molecular typing method called multi-locus sequence typing (MLST). The research shows that one sample from a cow grouped with other human isolates collected from urinary tract infections and bacteremia . This shows that *E. coli* from animals may be a cause of UTIs and bactermia in humans.

**Low-level fluoroquinolone resistance among *Camplyobacter jejuni* isolates in Australia.** L. Unicomb, J. Ferguson, R.J. Stafford, R. Ashbolt, M.D. Kirk, N.G. Becker, M.S. Patel, G.G. Gilbert, M. Valcanis and L. Mickan. *Clinical Infectious Diseases*, 2006. 42: 1368-1374.

**Summary:** Reports a study from five Australian states between 2001 and 2002 that looked into the susceptibility patterns of *Campylobacter jejuni*. Only two percent of isolates from locally acquired infections were resistant to ciprofloxacin, likely reflecting Australia's policy of restricting the use of fluoroquinolones in food production animals.

**First report of the emergence of CTX-M-type extended spectrum ß-Lactamases (ESBLs) as the predominant ESBL isolated in a U.S. health care system.** J. S. Lewis II, M. Herrena, B. Wickes, J.E. Patterson, J. H. Jorgensen. Antimicrobial Agents and Chemotherapy, 2007. 51(11): 4015-4021.

**Summary:** A study on Extended spectrum beta-lactamases (ESBLs) from a clinic in San Antonio Texas. ESBLs are enzymes produced by bacteria that can negate the use of certain newer antibiotics used in treating infections of *E. coli* or similar bacteria. The new ESBL enzyme described here as seen for the first time in the U.S. is located on a plasmid (a mobile element of DNA) within the bacterium. As plasmids can be readily passed between bacteria this new finding could have a wide health impact. The authors state "a worrisome trend with the emergence of these enzymes has been an increasing frequency of *E. coli* isolates from outpatients or patients hospitalized for a very brief period, suggesting community acquisition of these strains."

**Endemic and epidemic lineages of *Escherichia coli* that cause urinary tract infections.** A.R. Manges, H. Tabor, P. Tellis, C. Vincent and P. Tellier. *Emerging Infectious Diseases,* 2008. 14(10): 1575-1583.

**Summary:** Studies urinary tract infections (UTI) in women from California and Canada. Relatedness of the infections is apparent, as the profiles of the bacteria are identical. Multidrug-resistant *E. coli* outbreaks are the causative agent of the disease, and how these bacteria are acquired by the gut is unclear; however, the authors cite a previous study indicating that poultry and pork consumption may lead to the development of drug-resistant UTIs.

**Temporal changes in the prevalence of community-acquired antimicrobial-resistant urinary tract infection affected by *Escherichia coli* clonal group composition.** S.P. Smith, A.R. Manges, L.W. Riley. Clinical Infectious Diseases, 2008. 46: 689-695.

**Summary:** Reports on urinary tract infections (UTIs) from 1,667 patients over the course of 6 years. *E. coli* specimens were collected and characterized by molecular methods. Twelve percent of human UTI samples collected were found to be from a specific group, which from previous work has been shown to include *E. coli* that had been collected from food animals or retail poultry products. The collected human isolates were also shown to be resistant to trimethoprim-sulfamethoxazole at a rate of 49 percent. The authors suggest that contaminated food products may be a source of drug resistant UTIs.

**Hospital and societal costs of antimicrobial-resistant infections in a Chicago teaching hospital: Implications for antibiotic stewardship.** R.R. Roberts, B. Hota, I. Ahmad, R.D. Scott II, S.D. Foster, F. Abbasi, S. Schabowski, L.M. Kampe, G.G. Ciavarella, M. Supino, J. Naples, R. Cordell, S.B. Levy and R.A. Weinstein. *Clinical Infectious Diseases,* 2009. 49: 1175-1184.

**Summary:** Assesses the attributable cost associated with antimicrobial-resistant infections (ARI). Data were collected from patients admitted to a public teaching hospital in the Chicago area in the year 2000. Of 188 patients that met eligibility of ARI, the attributable medical cost of treatment ranged from $18,588 to $29,069 per patient. Social costs were $10.7 to $15.0 million, and total cost corrected to 2008 dollars was $13.35 million.

**Antibiotic management of Staphylococcus aureus infections in US children's hospitals, 1999-2008**. J.C. Herigon, A.L Hersh, J.S. Gerber, T.E. Zaoutis, J.G. Newland. *Pediatrics*, 2010. 125:e1294-e1300.

Summary: This study focuses on the rates of *S. aureus* infection in children under the age of 18 from 1999 until 2008. The authors also track the trend of antimicrobial use during that time period. Finds that *S. aureus* infections increased by a rate of more than 10-fold over the course of 10 years from 14.8 per 1000 admissions in 1999 to 35.7 per 1000 admissions in 2008. MRSA infections also increased 10-fold during the same period from 2.0 cases per 1000 admissions in 1999 to 20.7 cases per 1000 admissions in 2008. Increased use of clindamycin was most substantial (21 percent in 1999 to 63 percent in 2008) while linezolid also saw increased use between 2001 (when it became available) and 2008. The substantial use of clindamycin may lead to greater resistance and ineffective treatment of future *S. aureus* infections. The authors note that continuous monitoring of local *S. aureus* susceptibility patterns is needed as treatment patterns have changed over the past decade due to the emergence of community-associated MRSA.

**Genetic identity of aminoglycoside-resistance genes in *Escherichia coli* isolates from human and animal sources**. P. Ho, R.C. Wong, S.W. Lo, K. Chow, S.S. Wong, T. Que. *Journal of Medical Microbiology*, 2010. 59: 702-707.

Summary: A study in Hong Kong on *E. coli* isolates collected from food producing animals and humans (most from urinary tract infections). The group looked at the aminoglycocide (gentamicin) resistance characteristics of these isolates and found the main source of resistance was due to a gene called aacC2. The aacC2 gene was shown to exist in both human and animal *E. coli*. This suggests that gentamicin resistance in human *E. coli* urinary isolates can be attributed to resistance genes that are present in food-producing animals. Study illustrates when humans are in close contact with contaminated food, there is a risk of picking up antibiotic resistant *E. coli* that could lead to UTIs that are more difficult to treat.

**Food reservoir for *Escherichia coli* causing urinary tract infections.** C. Vincent, P. Boerlin, D. Daignault, C.M. Dozois, L. Dutil, C. Galanakis, R.J. Reid-Smith, P-P. Tellier, P.A. Tellis, K. Ziebell, A.R. Manges. Emerging Infectious Diseases, 2010. 16(1):88-95.

**Summary:** The design of this study was to see if a food reservoir exists for *E. coli* that may cause urinary tract infections. Sampling for *E. coli* was completed between 2005 and 2007 comprising clinical UTI samples, retail meats and restaurant/ready-to-eat foods. Upon comparison of these collected isolates by molecular methods the author's report that *E. coli* identified from retail chicken and other food sources are identical or nearly the same as those from human UTIs.

*For additional information on the Pew Campaign on Human Health and Industrial Farming, or on any of these studies, please contact Laura Rogers, Project Director, Pew Health Group, at (202) 552-2018 or* **lrogers@pewtrusts.org**.