


The Humane Society Institute for Science and Policy
Animal Studies Repository

2008

An HSUS Report: Human Health Implications of Non-Therapeutic Antibiotic Use in Animal Agriculture

The Humane Society of the United States

Follow this and additional works at: http://animalstudiesrepository.org/hsus_reps_environment_and_human_health

 Part of the [Agribusiness Commons](#), [Animal Studies Commons](#), and the [Other Public Health Commons](#)

Recommended Citation

The Humane Society of the United States, "An HSUS Report: Human Health Implications of Non-Therapeutic Antibiotic Use in Animal Agriculture" (2008). *HSUS Reports: Farm Industry Impacts on Environment and Human Health*. 11.
http://animalstudiesrepository.org/hsus_reps_environment_and_human_health/11

This Report is brought to you for free and open access by the Humane Society Institute for Science and Policy. It has been accepted for inclusion by an authorized administrator of the Animal Studies Repository. For more information, please contact eyahner@humanesociety.org.



An HSUS Report: Human Health Implications of Non-Therapeutic Antibiotic Use in Animal Agriculture

Abstract

For decades, the U.S. meat industry has fed medically important antibiotics to chickens, pigs, and cattle to accelerate their weight gain and prevent disease in the stressful and unhygienic conditions that typify industrialized animal agriculture production facilities. A strong scientific consensus exists, asserting that this practice fosters antibiotic resistance in bacteria to the detriment of human health. In response to this public health threat, the European Union has banned the non-therapeutic feeding of a number of antibiotics of human importance to farm animals. Given these serious concerns as well as recent data that suggest an overall lack of financial benefit, the U.S. meat industry should discontinue this risky practice.

Introduction

In 1951, the U.S. Food and Drug Administration (FDA) approved the addition of penicillin and tetracycline to chicken feed as growth promoters, encouraging pharmaceutical companies to mass-produce antibiotics for animal agriculture.¹ By the 1970s, nearly 100% of all birds commercially raised for meat in the United States were being fed antibiotics.² By the late-1990s, poultry producers were using 5 million kg (11 million lb) of antibiotics annually, more than a 300% increase from the 1980s.³ The thousands of tons of antibiotics used in animal agriculture are typically not for treatment of sick and diseased animals. Rather, the drugs are used for non-therapeutic purposes. More than 90% of U.S. pig farms, for example, feed the animals antibiotics for such non-treatment reasons as promotion of weight gain.⁴

Although the European Union has banned the use of a number of antibiotics of human importance in farm animals for non-treatment purposes since 1998, producers in the United States continue to mix more than one dozen different antibiotics into farm animal feed. The Union of Concerned Scientists (UCS) estimates that 70% of antimicrobials used in the United States are fed to chickens, pigs, and cattle for non-therapeutic purposes,⁵ primarily to birds raised for meat due to the scale and intensification of the poultry industry. Additionally, three antibiotics have been approved by the FDA for therapeutic use in the U.S. aquaculture industry, which consumes tons of antibiotics annually.⁶ Globally, it is estimated that half of the antibiotics produced in the world go not to human medicine but to usage on the farm.⁷

Antibiotics and Growth Promotion

The scientific community is still uncertain as to why the low-level feeding of antibiotics promotes faster weight gain in animals raised for meat.⁸ One possible explanation is the “resource allocation theory”: Since only a certain amount of energy, protein, and other nutrients enter an animal’s system at any one time, resources directed towards mounting an effective immune response are diverted from building muscle (meat), thereby introducing a potential trade-off between production traits desirable for industry and immunocompetence.^{9,10} According to this explanation, feeding antibiotics at a low level reduces immune system activity, freeing more resources for growth and weight gain.

For example, germ-free chicks raised in germ-free environments grow faster than chickens living in unsanitary conditions.¹¹ Exposure to the normal microbial flora of the gut are enough of an immune stimulus to reduce

growth rates significantly.¹² Indeed, even without tissue damage or evidence of disease, immune function can divert energy from maximal growth.¹³ Animals raised in more sanitary environments and given antibiotics experience no change in growth rates, whereas animals in commercial production who are fed antibiotics demonstrate a remarkable spurt in growth.¹⁴

The maintenance of an effective immune system is metabolically very costly.¹⁵ Macrophage immune cells burn about half as much energy as maximally functioning heart muscle cells.¹⁶ Because antibodies are made of protein, when the body is producing thousands of antibodies per second, there may be less protein available for growth. One study showed that chickens capable of mounting a decent antibody response have lower weight and lower feed efficiency than chickens with suboptimal antibody production.¹⁷

Immune challenges can result in a greater than 20% decline in daily weight gain for farm animals, while increasing protein demands as much as 30%,¹⁸ demonstrating the inverse relationship between growth and immunity. In the unhygienic conditions of intensive confinement animal production operations, normal physiological processes like growth may be impaired in light of the infectious load to which animals are exposed. A constant influx of antibiotics may reduce that load.¹⁹

Unnaturally rapid growth* due to genetic manipulation can result in pathological conditions that can further stress the animals, such as painful crippling leg and joint deformities.²⁰ Animal agriculture industry journal *Feedstuffs* reports that “broilers [chickens raised for meat] now grow so rapidly that the heart and lungs are not developed well enough to support the remainder of the body, resulting in congestive heart failure and tremendous death losses.”²¹ Pharmacological growth acceleration adds additional stress.

Concern regarding the relationship between inappropriate production conditions and antibiotic usage spans decades. “Present production is concentrated in high-volume, crowded, stressful environments, made possible in part by the routine use of antibacterial in feed,” the congressional Office of Technology Assessment wrote in 1979. “Thus the current dependency on low-level use of antibacterial to increase or maintain production, while of immediate benefit, also could be the Achilles’ heel of present production methods.”²²

Potential Risks to Human Health

Indiscriminate use of antibiotics may lead to the evolution of resistance by selecting directly for drug-resistant pathogens as well as for mobile genetic elements carrying resistance determinants to both human and non-human animal pathogens. Antibiotics and antibiotic-resistant bacteria can be found in the air, groundwater, and soil around farms and on retail meat,²³ and people can be exposed to these pathogens through infected meat, vegetables fertilized with raw manure, and water supplies contaminated by farm animal waste.²⁴

According to the Centers for Disease Control and Prevention (CDC), at least 17 classes of antimicrobials are approved for farm animal growth promotion in the United States,²⁵ including many families of antibiotics that are critical for treating human disease, such as penicillin, tetracycline, and erythromycin.²⁶ As the bacteria become more resistant to the antibiotics fed to chickens and other animals raised for meat, they may become more resistant to the antibiotics needed to treat sick people. Resistance genes that emerge can then be swapped between bacteria. Italian researchers published a DNA fingerprinting study in 2007 showing that these antibiotic-resistance genes could be detected directly in meat products from chickens and pigs.²⁷

The world’s leading medical, agricultural, and veterinary authorities have reached consensus that antibiotic overuse in animal agriculture is contributing to human public health problems. A joint scientific analysis co-sponsored by the World Health Organization, the Food and Agriculture Organization of the United Nations, and the World Organisation for Animal Health concluded: “[T]here is clear evidence of adverse human health

* For more information, see: “An HSUS Report: Welfare Issues with Selective Breeding for Rapid Growth in Broiler Chickens and Turkeys” at www.hsus.org/farm/resources/research/practices/fast_growth_chickens_turkeys.html.

consequences [from agricultural use of antibiotics, including]...infections that would not have otherwise occurred, increased frequency of treatment failures (in some cases death) and increased severity of infections.”

This conclusion was derived from multiple lines of evidence including epidemiological studies tracing drug-resistant human infections to specific farm animal production facilities; temporal associations demonstrating antibiotic use in farm animal populations preceding the emergence of the same resistance in humans; and microbial studies showing that antibiotic-resistant bacteria from farm animals not only infect humans, but may transfer that resistance to other bacteria that colonize the human gut.²⁸ The strongest evidence may be data from Europe’s experience, which showed that after antibiotics were banned for growth promotion in animal agriculture, there was a subsequent decrease in the levels of antibiotic-resistant bacteria in farm animals, on meat, and within the general human population.²⁹

According to the head of the CDC’s food poisoning surveillance program, “[t]he reason we’re seeing an increase in antibiotic resistance in foodborne diseases [in the United States] is because of antibiotic use on the farm.”³⁰ However, antibiotic resistance is escalating not only in the United States, but globally. The Director-General of the World Health Organization fears that this worldwide rise in antibiotic-resistant “superbugs” is threatening to “send the world back to a pre-antibiotic age.”³¹ As resistant bacteria become resistant to second- and third-line drugs, CDC medical epidemiologist David M. Bell was quoted as saying that “we’re skating just along the edge.”³² The bacteria seem to be evolving resistance faster than our ability to create new antibiotics. “It takes us seventeen years to develop an antibiotic,” explains National Institutes of Health medical historian David Morens. “But a bacterium can develop resistance virtually in minutes. It’s as if we’re putting our best players on the field, but the bench is getting empty, while their side has an endless supply of new players.”³³ Remarked University of Illinois microbiologist Abigail Salvers, “Never underestimate an adversary that has a three-point-five-billion-year head start.”³⁴

Case Studies: Drug-Resistant *Campylobacter*, *Salmonella*, *E. coli*, MRSA, and Influenzavirus A

The poultry industry blames the dramatic rise in antibiotic-resistant bacteria on overuse of all antibiotics, including the over-prescription of antibiotics by physicians for their patients.³⁵ While doctors undoubtedly play a role, according to the CDC, evidence is accumulating that overuse by animal agriculture industries is a public health threat.³⁶ The September 2005 FDA decision against the Bayer Corporation is illustrative of this point.

Campylobacter is a spiral-shaped poultry bacterium that corkscrews its way into the lining of the intestine “with a speed that cannot be matched by other bacteria.”³⁷ Typically, *Campylobacter* causes only a self-limited diarrheal illness (“stomach flu”) that does not require antibiotics. However, if the gastroenteritis is particularly severe or if doctors suspect that the bacteria may be crossing the gut into the bloodstream, the initial preferred drug is typically a quinolone antibiotic like Cipro. Quinolone antibiotics have been used in human medicine since the 1960s, but widespread antibiotic-resistant *Campylobacter* did not arise until after quinolones were licensed for use in chicken production in the mid-1990s.³⁸ In countries like Australia, which reserved quinolones exclusively for human use, resistant bacteria are practically unknown.³⁹

The FDA concluded that the use of Cipro-like antibiotics in chicken production compromised the treatment of nearly 10,000 Americans annually, meaning that thousands of people infected with *Campylobacter* who sought medical treatment were initially treated with an antibiotic to which the bacteria was resistant,⁴⁰ forcing the doctors to switch to more powerful drugs. A study involving thousands of patients with *Campylobacter* infections showed that resistant strains led to up to nearly ten times more complications—including infections of the brain, the blood, and, the most frequent serious complication they noted, death.⁴¹

When the FDA announced that it intended to join other countries and ban quinolone antibiotic use on U.S. poultry farms, the drug manufacturer Bayer initiated legal action that successfully delayed the ban for five years.⁴² During that time, Bayer continued to dominate the market, estimated at \$15 million annually,⁴³ and resistance continued to climb.⁴⁴

Antibiotic-resistant *Salmonella* has also led to serious human medical complications.⁴⁵ Foodborne *Salmonella* emerged in the U.S. Northeast in the late-1970s and has since spread throughout North America. One theory holds that multidrug-resistant *Salmonella* was disseminated worldwide in the 1980s via contaminated feed made out of farmed fish[†] who had been fed routine antibiotics.⁴⁶ The practice of using antimicrobial agents in fish farming has been criticized by the CDC.⁴⁷ The CDC is especially concerned about the recent rapid dissemination of a strain resistant to nine separate antibiotics, including the primary treatment used in children.⁴⁸ *Salmonella* kills hundreds of Americans every year, hospitalizes thousands, and sickens more than 1 million.⁴⁹ Under industry pressure, the FDA recently delayed and then revoked its ban on the off-label use of third-generation cephalosporins in animal agriculture,⁵⁰ the drugs of choice for invasive *Salmonella* infections in children.⁵¹

Evidence is mounting that antibiotic-resistant bladder infections may be tied to farm animal drug use as well.⁵² Urinary tract infections (UTIs) are the most common bacterial infections in women of all ages,⁵³ affecting millions every year in the United States. From a physician's perspective, UTIs are increasingly difficult to treat, as antibiotic resistance among the chief pathogen, *E. coli*, becomes more common.⁵⁴

Perhaps the most familiar *E. coli* strain is *E. coli* O157:H7, perhaps best known for a Jack-in-the-Box restaurant outbreak that sickened hundreds and killed four children in 1993. Clinically, human infection starts as hemorrhagic colitis (profuse bloody diarrhea) and can progress to kidney failure, seizures, coma, and death. This class of toxin-producing foodborne bacteria remains the leading cause of acute kidney failure in North American children.⁵⁵ Though fewer than 100,000 Americans get infected every year and fewer than 100 die,⁵⁶ millions get "extraintestinal" *E. coli* infections—UTIs that can invade the bloodstream and are responsible for an estimated 36,000 deaths annually in the United States.⁵⁷ While the source of human *E. coli* O157:H7 infection is known to be fecal contamination from the meat, dairy, and egg industries,⁵⁸ only recently have scientists traced the path of UTI-type *E. coli*.

Medical researchers at the University of Minnesota took more than 1,000 food samples from multiple retail markets and found evidence of fecal contamination in 69% of the pork and beef tested, and 92% of the poultry samples as evidenced by the presence of *E. coli*. More than 80% of the *E. coli* they recovered from beef, pork, and poultry products were resistant to one or more antibiotics, and greater than half of the samples of poultry bacteria were resistant to more than five drugs. Nearly half of the poultry samples were contaminated with the extraintestinal pathogenic *E. coli* bacteria, abbreviated ExPEC, further supporting the notion that UTI-type *E. coli* may be foodborne pathogens as well.⁵⁹ Scientists suspect that by eating chickens and other animal products, women infect their lower intestinal tract with these antibiotic-resistant bacteria, which can then migrate into their bladder.⁶⁰

Alarming high rates of methicillin-resistant *Staphylococcus aureus* (MRSA) detection in farm animals and retail meat in Europe has led to increased scrutiny of the agricultural use of antibiotics. The Dutch Agriculture, Nature, and Food Standards Minister, Cees Veerman, was recently reported as saying that "the high usage of antibiotics in livestock farming is the most important factor in the development of antibiotic resistance, a consequence of which is the spread of resistant microorganisms (MRSA included) in animal populations."⁶¹ The 2008 discovery of MRSA in North American pigs suggests the potential public health risk attributed to farm animal-associated MRSA may be a global phenomenon.⁶² Recently, the majority (70%) of pigs tested in Iowa and Illinois were found to be carrying MRSA.⁶³ According to 2009 published findings from Louisiana State University, 5.6% of retail pork samples were contaminated with human-type MRSA.⁶⁴

Drug resistance is not limited to bacteria. In the 2005 *Washington Post* exposé, "Bird Flu Drug Rendered Useless," it was revealed that for years Chinese chicken farmers had been lacing the animals' water supply with the antiviral drug amantadine to prevent economic losses from bird flu.⁶⁵ The use of amantadine in the water

[†] For more information, see: "An HSUS Report: The Welfare of Animals in the Aquaculture Industry" at www.hsus.org/farm/resources/research/welfare/welfare_aquaculture.html.

supply of commercial poultry as prophylaxis against avian influenza[‡] was pioneered in the United States after the 1983 outbreak in Pennsylvania. Even then it was shown that drug-resistant mutants arose within nine days of application.⁶⁶ The practice in China has been blamed for the emergence of widespread viral resistance to a life-saving drug that could be used in a human pandemic.⁶⁷ “In essence,” wrote Frederick Hayden, the Stuart S. Richardson Professor of Clinical Virology in Internal Medicine at the University of Virginia School of Medicine, “this finding means that a whole class of antiviral drugs has been lost as treatment for this virus.”⁶⁸

Calls to Ban the Use of Non-Therapeutic Antibiotics in Animal Agriculture

The European science magazine *New Scientist* editorialized in 1968 that the use of antibiotics to make animals grow faster “should be abolished altogether.”⁶⁹ Pleas for caution in the overuse of antibiotics can be traced back farther to the discoverer of penicillin himself, Sir Alexander Fleming, who told *The New York Times* in 1945 that inappropriate use of antibiotics could lead to the selection of “mutant forms” resistant to the drugs.⁷⁰ While the European Union banned the use of certain medically important antibiotics as farm animal growth promoters years ago,⁷¹ no such comprehensive step has yet taken place in the United States.

The American Medical Association, the American Public Health Association, the Infectious Diseases Society of America, and the American Academy of Pediatrics are among the 350 organizations nationwide that have endorsed efforts to phase out the use of antibiotics important to human medicine as animal feed additives.⁷²

In 2001, Donald Kennedy, editor-in-chief of *Science*, and Stanley Falkow, professor of Microbiology and Immunology at Stanford University, wrote that the continued feeding of medically important antibiotics to farm animals to promote growth goes against a “strong scientific consensus that it is a bad idea.”⁷³ An editorial the same year in the *New England Journal of Medicine* entitled “Antimicrobial Use in Animal Feed—Time to Stop” came to a similar conclusion.⁷⁴

Despite the consensus among the world’s scientific authorities, debate on this issue continues. The editorial board of *Nature Reviews Microbiology* journal offered an explanation: “A major barrier is the fact that many scientists involved in agriculture and food animal producers refuse to accept that the use of antibiotics in livestock has a negative effect on human health. . . . It is understandable that the food-producing industry wishes to protect its interests. However, microbiologists are aware of, and understand, the weight of evidence linking the sub-therapeutic use of antibiotics with the emergence of resistant bacteria. Microbiologists also understand the threat that antibiotic resistance poses to public health. As a profession, we must be vocal in supporting any policy that diminishes this threat.”⁷⁵

An editorial in the *Western Journal of Medicine* identified erroneous claims made by the pharmaceutical and meat industries and concluded: “The intentional obfuscation of the issue by those with profit in mind is an uncomfortable reminder of the long and ongoing battle to regulate the tobacco industry, with similar dismaying exercises in political and public relations lobbying and even scandal.”⁷⁶

This is not the first time the animal agriculture industry has used growth-promoting drugs at the potential expense of human health. Decades ago, the poultry industry pioneered the use of the synthetic growth hormone diethylstilbestrol (DES) in agriculture, despite the fact that it was a known carcinogen. Although some women were prescribed DES during pregnancy—a drug advertised by manufacturers to produce “bigger and stronger babies”⁷⁷—the chief exposure for Americans to DES was through residues in meat. Even after it was proven that women who were exposed to DES gave birth to daughters with high rates of vaginal cancer, the meat industry was able to stonewall a ban on DES in chicken feed for years.⁷⁸ According to a Stanford University health policy analyst, only after a study found DES residues in marketed poultry meat at 342,000 times the levels found to be carcinogenic did the FDA finally ban it as a growth promoter in poultry production in 1979.⁷⁹

[‡] For more information, see: “An HSUS Report: Human Health Implications of Intensive Poultry Production and Avian Influenza” at www.hsus.org/farm/resources/research/pubhealth/public_health_avian_influenza.html.

Kennedy, who served as commissioner of the U.S. Food and Drug Administration from 1977 to 1979, describes the antibiotic debate as a “struggle between good science and strong politics.” When meat production interests pressured Congress to shelve an FDA proposal to limit the practice, Kennedy concluded: “Science lost.”⁸⁰

Financial Ramifications

The U.S. Government Accountability Office released a 2004 report on the use of antibiotics as growth promoters in farm animals. Though the GAO acknowledged that the bulk of studies “found that the use of antibiotics in animals poses significant risks for human health,” a ban could, in part, result in a “reduction in profits” for the industry. The report published fears that even a partial ban might “increase costs to producers, decrease production, and increase retail prices to consumers.”⁸¹

An unsubstantiated industry estimate⁸² of the costs associated with a total ban on the widespread feeding of antibiotics to farm animals in the United States is an increase in the price of poultry products from 1-2 cents per pound and an increase in the price of pork or beef between 3-6 cents per pound. This could cost the average U.S. meat-eating consumer as much as \$9.72 a year.⁸³

Antibiotic-resistant infections in the United States from all sources may cost billions of dollars every year⁸⁴ and may kill 63,000 people annually.⁸⁵

A major analysis of the elimination of growth-promoting antibiotics in Denmark, one of the world’s largest pork producers,⁸⁶ showed that the move led to a marked reduction in bacterial antibiotic resistance without significant adverse effects on productivity.⁸⁷ U.S. industry, however, has argued that the Danish experience cannot be extrapolated to the United States.⁸⁸ This led Johns Hopkins University researchers to carry out an economic analysis based on data from Perdue, one of the largest poultry producers in the United States.

The Johns Hopkins University Bloomberg School of Public Health study, published in 2007, examined data from 7 million chickens and concluded that the use of antibiotics in chicken feed *increases* costs of poultry production. “Contrary to the long-held belief that a ban against GPAs [growth-promoting antibiotics] would raise costs to producers and consumers,” the researchers concluded, “these results using a large-scale industry study demonstrate the opposite.”⁸⁹ They found that the conditions in Perdue’s facilities were such that antibiotics did accelerate the birds’ growth rates, but the money saved was insufficient to offset the cost of the antibiotics themselves. Growth-promoting antibiotics may end up costing producers more in the end than if they hadn’t used antibiotics at all. A similar study at Kansas State University also showed suggested no economic benefits from feeding antibiotics to “finishing” pigs.⁹⁰

Conclusion

The practice of feeding antibiotics to farm animals to promote faster growth is being phased out in countries around the world to protect the public’s health. Given the lack of demonstrable benefits, the U.S. meat industry should heed the call of the U.S. public health community and global authorities to follow this lead. With few, if any, new classes of antibiotics in clinical development,⁹¹ an expert on antibiotics at the Institute for Agriculture and Trade Policy warned that “we’re sacrificing a future where antibiotics will work for treating sick people by squandering them today for animals that are not sick at all.”⁹²

¹ Boyd W. 2001. Making meat: science, technology, and American poultry production. *Technology and Culture* 42(4):631-64.

² Office of Technology Assessment. 1979. *Drugs in Livestock Feed*. Volume 1: Technical Report (Washington, DC: U.S. Government Printing Office, p. 1). www.princeton.edu/~ota/disk3/1979/7905/7905.PDF. Accessed November 14, 2008.

³ Mellon M, Benbrook C, and Benbrook KL. 2001. *Hogging It! Estimates of Antimicrobial Abuse in Livestock* (Cambridge, MA: Union of Concerned Scientists).

-
- ⁴ U.S. Department of Agriculture, Animal and Plant Health Inspection Service, and Veterinary Services. 1996. Reference of 1995 U.S. grower/finisher health & management practices. <http://ageconsearch.umn.edu/bitstream/32770/1/swin02.pdf>. Accessed November 14, 2008.
- ⁵ Mellon M, Benbrook C, and Benbrook KL. 2001. Hogging It! Estimates of Antimicrobial Abuse in Livestock (Cambridge, MA: Union of Concerned Scientists).
- ⁶ Viola C and DeVincent SJ. 2006. Overview of issues pertaining to the manufacture, distribution, and use of antimicrobials in animals and other information relevant to animal antimicrobial use data collection in the United States. *Preventive Veterinary Medicine* 73(2-3):111-31.
- ⁷ World Health Organization. 2002. Use of antimicrobials outside human medicine and resultant antimicrobial resistance in humans. www.who.int/mediacentre/factsheets/fs268/en/. Accessed November 14, 2008.
- ⁸ Graham JP, Boland JJ, and Silbergeld E. 2007. Growth promoting antibiotics in food animal production: an economic analysis. *Public Health Reports* 122(1):79-87.
- ⁹ Norris K and Evans MR. 2000. Ecological immunology: life history trade-offs and immune defense in birds. *Behavioral Ecology* 11(1):19-26.
- ¹⁰ Rauw WM, Kanis E, Noordhuizen-Stassen EN, and Grommers FJ. 1998. Undesirable side effects of selection for high production efficiency in farm animals: a review. *Livestock Production Science* 56(1):15-33.
- ¹¹ Coates ME, Fuller R, Harrison GF, Lev M, and Suffolk SF. 1963. A comparison of the growth of chicks in the Gustafsson germ-free apparatus and in a conventional environment, with and without dietary supplements of penicillin. *British Journal of Nutrition* 17(1):141-50.
- ¹² Mangel M and Stamps J. 2001. Trade-offs between growth and mortality and the maintenance of individual variation in growth. *Evolutionary Ecology Research* 3:583-93.
- ¹³ Klasing KC, Laurin DE, Peng RK, and Fry DM. 1987. Immunologically mediated growth depression in chicks: influence of feed intake, corticosterone and interleukin-1. *The Journal of Nutrition* 117(9):1629-37.
- ¹⁴ Office of Technology Assessment. 1979. *Drugs in Livestock Feed. Volume 1: Technical Report* (Washington, DC: U.S. Government Printing Office). www.princeton.edu/~ota/disk3/1979/7905/7905.PDF. Accessed November 14, 2008.
- ¹⁵ Lochmiller RL and Deerenberg C. 2000. Trade-offs in evolutionary immunology: just what is the cost of immunity? *Oikos* 88(1):87-98.
- ¹⁶ Newsholme P and Newsholme EA. 1989. Rates of utilization of glucose, glutamine and oleate and formation of end-products by mouse peritoneal macrophages in culture. *Biochemical Journal* 261(1):211-18.
- ¹⁷ Gross WB and Siegel PB. 1988. Environment-genetic influences on immunocompetence. *Journal of Animal Science* 66:2091-4.
- ¹⁸ Spurlock ME, Frank GR, Willis GM, Kuske JL, and Cornelius SG. 1997. Effect of dietary energy source and immunological challenge on growth performance and immunological variables in growing pigs. *Journal of Animal Science* 75(3):720-6.
- ¹⁹ Office of Technology Assessment. 1979. *Drugs in Livestock Feed. Volume 1: Technical Report* (Washington, DC: U.S. Government Printing Office). www.princeton.edu/~ota/disk3/1979/7905/7905.PDF. Accessed November 14, 2008.
- ²⁰ Kestin SC, Knowles TG, Tinch AE, and Gregory NG. 1992. Prevalence of leg weakness in broiler chickens and its relationship with genotype. *The Veterinary Record* 131(9):190-4.
- ²¹ Martin D. 1997. Researcher studying growth-induced diseases in broilers. *Feedstuffs*, May 26.
- ²² Office of Technology Assessment. 1979. *Drugs in Livestock Feed. Volume 1: Technical Report* (Washington, DC: U.S. Government Printing Office, p. 41). www.princeton.edu/~ota/disk3/1979/7905/7905.PDF. Accessed November 14, 2008.
- ²³ Smith DL, Dushoff J, and Morris JG. 2005. Agricultural antibiotics and human health. *PLoS Medicine* 2(8):e232.
- ²⁴ Acar JF and Moulin G. 2006. Antimicrobial resistance at farm level. *Revue Scientifique et Technique (International Office of Epizootics)* 25(2):775-92.
- ²⁵ Anderson AD, McClellan J, Rossiter S, and Angulo FJ. 2003. Public health consequences of use in antimicrobial agents in agriculture. In: Knobler SL, Lemon SM, Najafi M, and Burroughs T (eds.), *The Resistance Phenomenon in Microbes and Infectious Disease Vectors: Implications for Human Health and*

-
- Strategies for Containment—Workshop Summary (Washington, DC: The National Academies Press, pp. 231-43). <http://fermat.nap.edu/openbook/0309088542/html/231.html>. Accessed November 14, 2008.
- ²⁶ Mellon M, Benbrook C, and Benbrook KL. 2001. Hogging It! Estimates of Antimicrobial Abuse in Livestock (Cambridge, MA: Union of Concerned Scientists).
- ²⁷ Garofalo C, Vignaroli C, Zandri G, et al. 2007. Direct detection of antibiotic resistance genes in specimens of chicken and pork meat. *International Journal of Food Microbiology* 113(1):75-83.
- ²⁸ Food and Agriculture Organization of the United Nations, World Health Organization, and World Organization for Animal Health. 2003. Expert workshop on non-human antimicrobial usage and antimicrobial resistance: scientific assessment. Geneva, Switzerland, December 1-5. www.who.int/foodsafety/publications/micro/en/amr.pdf. Accessed November 14, 2008.
- ²⁹ Smith DL, Dushoff J, and Morris JG. 2005. Agricultural antibiotics and human health. *PLoS Medicine* 2(8):e232.
- ³⁰ Drexler M. 2002. *Secret Agents: The Menace of Emerging Infections* (Washington, DC: Joseph Henry Press).
- ³¹ World Health Organization. 2000. Drug resistance threatens to reverse medical progress. Press release issued June 12. www.who.int/inf-pr-2000/en/pr2000-41.html. Accessed November 14, 2008.
- ³² Drexler M. 2002. *Secret Agents: The Menace of Emerging Infections* (Washington, DC: Joseph Henry Press).
- ³³ Drexler M. 2002. *Secret Agents: The Menace of Emerging Infections* (Washington, DC: Joseph Henry Press).
- ³⁴ Drexler M. 2002. *Secret Agents: The Menace of Emerging Infections* (Washington, DC: Joseph Henry Press, p. 145).
- ³⁵ Frontline. 2002. Modern meat: is your meat safe? Antibiotic debate overview. www.pbs.org/wgbh/pages/frontline/shows/meat/safe/overview.html. Accessed November 14, 2008.
- ³⁶ Anderson AD, McClellan J, Rossiter S, and Angulo FJ. 2003. Public health consequences of use in antimicrobial agents in agriculture. In: Knobler SL, Lemon SM, Najafi M, and Burroughs T (eds.), *The Resistance Phenomenon in Microbes and Infectious Disease Vectors: Implications for Human Health and Strategies for Containment—Workshop Summary* (Washington, DC: The National Academies Press, pp. 231-43). <http://fermat.nap.edu/openbook/0309088542/html/231.html>. Accessed November 14, 2008.
- ³⁷ Drexler M. 2002. *Secret Agents: The Menace of Emerging Infections* (Washington, DC: Joseph Henry Press).
- ³⁸ Gupta A, Nelson JM, Barrett TJ, et al. 2004. Antimicrobial resistance among *Campylobacter* strains, United States, 1997-2001. *Emerging Infectious Diseases* 10(6):1102-9. www.cdc.gov/ncidod/EID/vol10no6/03-0635.htm. Accessed November 14, 2008.
- ³⁹ Unicomb L, Ferguson J, Riley TV, and Collignon P. 2003. Fluoroquinolone resistance in *Campylobacter* absent from isolates, Australia. *Emerging Infectious Diseases* 9(11):1482-3.
- ⁴⁰ Food and Drug Administration, Center for Veterinary Medicine. 2001. The human health impact of fluoroquinolone resistant *Campylobacter* attributed to the consumption of chicken. www.fda.gov/cvm/documents/revisedRA.pdf. Accessed November 14, 2008.
- ⁴¹ Helms M, Simonsen J, Olsen KE, and Mølbak K. 2005. Adverse health events associated with antimicrobial drug resistance in *Campylobacter* species: a registry-based cohort study. *The Journal of Infectious Diseases* 191(7):1050-5.
- ⁴² Kaufman M. 2005. Ending battle with FDA, Bayer withdraws poultry antibiotic. *The Washington Post*, September 9, p. A03. www.washingtonpost.com/wp-dyn/content/article/2005/09/08/AR2005090801918.html. Accessed November 14, 2008.
- ⁴³ Palmer E. 2002. Bayer urged to eliminate animal version of Cipro. *Kansas City Star*, February 20. www.keepantibioticsworking.com/news/news.cfm?News_ID=176. Accessed November 14, 2008.
- ⁴⁴ Keep Antibiotics Working. 2005. Keep Antibiotics Working praises FDA's first ever ban of agricultural drug due to antibiotic-resistance effects in humans. Press release issued July 28. www.keepantibioticsworking.com/new/resources_library.cfm?refID=73539. Accessed November 14, 2008.
- ⁴⁵ Varma JK, Greene KD, Ovitt J, Barrett TJ, Medalla F, and Angulo FJ. 2005. Hospitalization and antimicrobial resistance in *Salmonella* outbreaks, United States, 1984-2002. *Emerging Infectious Diseases* 11(6):943-6. www.cdc.gov/ncidod/EID/vol11no06/pdfs/04-1231.pdf. Accessed November 14, 2008.
- ⁴⁶ Angulo FJ and Griffin PM. 2000. Changes in antimicrobial resistance in *Salmonella enterica* serovar Typhimurium. *Emerging Infectious Diseases* 6(4):436-7. www.cdc.gov/ncidod/eid/vol6no4/angulo_letter.htm. Accessed November 14, 2008.

- ⁴⁷ Angulo F. 1999. Use of antimicrobial agents in aquaculture: potential for public health impact. National Aquaculture Association. Center for Disease Control Memo to the Record, October 18. www.thenaa.net/?dl_id=12. Accessed November 14, 2008.
- ⁴⁸ Centers for Disease Control and Prevention. 2002. Outbreak of multidrug-resistant *Salmonella* Newport—United States, January-April 2002. Morbidity and Mortality Weekly Report 51(25):545-8. www.cdc.gov/mmwr/preview/mmwrhtml/mm5125a1.htm. Accessed November 14, 2008.
- ⁴⁹ Mead PS, Slutsker L, Dietz V, et al. 1999. Food-related illness and death in the United States. Emerging Infectious Diseases 5(5):607-25. www.cdc.gov/ncidod/eid/Vol5no5/mead.htm. Accessed November 14, 2008.
- ⁵⁰ Mundy A and Favole F. 2008. FDA calls off ban on animal antibiotics. Wall Street Journal, December 9. http://online.wsj.com/article/SB122887467038993653.html?mod=googlenews_wsj. Accessed January 2, 2009.
- ⁵¹ 2008. FDA bans extralabel use of cephalosporins in food animals. Veterinary Practice News, July 3.
- ⁵² Ramchandani M, Manges AR, DebRoy C, Smith SP, Johnson JR, and Riley LW. 2005. Possible animal origin of human-associated, multidrug-resistant, uropathogenic *Escherichia coli*. Clinical Infectious Diseases 40(2):251-7.
- ⁵³ Foxman B. 2002. Epidemiology of urinary tract infections: incidence, morbidity, and economic costs. The American Journal of Medicine 113(1):S5-13.
- ⁵⁴ Centers for Disease Control and Prevention. 2005. Urinary tract infections. www.cdc.gov/ncidod/dbmd/diseaseinfo/urinarytractinfections_t.htm. Accessed November 14, 2008.
- ⁵⁵ National Institutes of Health, National Institute of Allergy and Infectious Diseases. 2007. Complications, *E. coli*. <http://www3.niaid.nih.gov/topics/ecoli/Complications.htm>. Accessed November 14, 2008.
- ⁵⁶ Mead PS, Slutsker L, Dietz V, et al. 1999. Food-related illness and death in the United States. Emerging Infectious Diseases 5(5):607-25. www.cdc.gov/ncidod/eid/Vol5no5/mead.htm. Accessed November 14, 2008.
- ⁵⁷ Phillips ML. 2005. ExPECTing the worst. Environmental Health Perspectives 113(6):A371. www.ehponline.org/docs/2005/113-6/forum.html. Accessed November 14, 2008.
- ⁵⁸ Schoeni JL and Doyle MP. 1994. Variable colonization of chickens perorally inoculated with *Escherichia coli* O157:H7 and subsequent contamination of eggs. Applied and Environmental Microbiology 60(8):2958-62.
- ⁵⁹ Johnson JR, Kuskowski MA, Smith K, O'Bryan TT, and Tatini S. 2005. Antimicrobial-resistant and extraintestinal pathogenic *Escherichia coli* in retail foods. The Journal of Infectious Diseases 191(7):1040-9.
- ⁶⁰ Brownlee C. 2005. The beef about UTIs. Science News, January 15. www.sciencenews.org/view/generic/id/5782/title/The_Beef_about_UTIs. Accessed November 14, 2008.
- ⁶¹ Soil Association. 2007. MRSA in farm animals and meat: a new threat to human health. [www.soilassociation.org/Web/SA/saweb.nsf/89d058cc4dbeb16d80256a73005a2866/5cae3a9c3b4da4b880257305002daadf/\\$FILE/MRSA_report.pdf](http://www.soilassociation.org/Web/SA/saweb.nsf/89d058cc4dbeb16d80256a73005a2866/5cae3a9c3b4da4b880257305002daadf/$FILE/MRSA_report.pdf). Accessed November 14, 2008.
- ⁶² Khanna T, Friendship R, Dewey C, and Weese JS. 2008. Methicillin resistant *Staphylococcus aureus* colonization in pigs and pig farmers. Veterinary Microbiology 128(3-4):298-303.
- ⁶³ Goldberg R, Roach S, Wallinga D, and Mellon M. 2008. The risks of pigging out on antibiotics. Science 321(5894):1294.
- ⁶⁴ Pu S, Han F, and Ge B. 2009. Isolation and characterization of methicillin-resistant *Staphylococcus aureus* strains from Louisiana retail meats. Applied and Environmental Microbiology 75(1):265-7.
- ⁶⁵ Sipress A. 2005. Bird flu drug rendered useless: Chinese chickens given medication made for humans. The Washington Post, June 18, p. A01. www.washingtonpost.com/wp-dyn/content/article/2005/06/17/AR2005061701214.html. Accessed November 14, 2008.
- ⁶⁶ Webster RG, Kawaoka Y, Bean WJ, Beard CW, and Brugh M. 1985. Chemotherapy and vaccination: a possible strategy for the control of highly virulent influenza virus. Journal of Virology 55(1):173-6.
- ⁶⁷ Sipress A. 2005. Bird flu drug rendered useless: Chinese chickens given medication made for humans. The Washington Post, June 18, p. A01. www.washingtonpost.com/wp-dyn/content/article/2005/06/17/AR2005061701214.html. Accessed November 14, 2008.
- ⁶⁸ Hayden FG. 2004. Pandemic influenza: is an antiviral response realistic? Pediatric Infectious Disease Journal 23(11):S262-9.
- ⁶⁹ New Scientist. 1968. A bitter reckoning. New Scientist, January 4, pp. 14-5.
- ⁷⁰ Alanis AJ. 2005. Resistance to antibiotics: are we in the post-antibiotic era? Archives of Medical Research 36(6):697-705.

-
- ⁷¹ BBC News. 1998. EU bans farm antibiotics. BBC News, December 14. <http://news.bbc.co.uk/2/hi/europe/234566.stm>. Accessed November 14, 2008.
- ⁷² Keep Antibiotics Working. 2007. Kennedy, Snowe & Slaughter introduce AMA-backed bill to cut antibiotic resistance linked to misuse of antibiotics in animal agriculture. Press release issued February 12. www.keepantibioticsworking.com/new/resources_library.cfm?RefID=97314. Accessed November 14, 2008.
- ⁷³ Falkow S and Kennedy D. 2001. Antibiotics, animals, and people—again! *Science* 291(5503):397.
- ⁷⁴ Gorbach SL. 2001. Antimicrobial use in animal feed—time to stop. *The New England Journal of Medicine* 345(16):1202-3.
- ⁷⁵ Nature Reviews, Microbiology. 2003. Will antibiotic misuse now stop? *Nature Reviews, Microbiology* 1(2):85.
- ⁷⁶ Heilig S, Lee P, and Breslow L. 2002. Curtailing antibiotic use in agriculture: it is time for action: this use contributes to bacterial resistance in humans. *Western Journal of Medicine* 176(1):9-11.
- ⁷⁷ Dutton DB, Preston TA, and Pfund NE. 1988. *Worse than the Disease: Pitfalls of Medical Progress* (Cambridge, U.K.: Cambridge University Press, p. 31).
- ⁷⁸ Epstein SS. 1989. U.S. policy turns blind side to dangers of meat additives. *Austin American-Statesman*, March 8, p. A15.
- ⁷⁹ Dutton DB, Preston TA, and Pfund NE. 1988. *Worse than the Disease: Pitfalls of Medical Progress* (Cambridge, U.K.: Cambridge University Press), citing: *Congressional Record*, Appendix, February 21, 1957, p. A1352-4.
- ⁸⁰ Falkow S and Kennedy D. 2001. Antibiotics, animals, and people—again! *Science* 291(5503):397.
- ⁸¹ United States General Accounting Office. 2004. Antibiotic resistance: federal agencies need to better focus efforts to address risk to humans from antibiotic use in animals. Report to Congressional Requesters, April. www.gao.gov/new.items/d04490.pdf. Accessed November 14, 2008.
- ⁸² Graham JP, Boland JJ, and Silbergeld E. 2007. Growth promoting antibiotics in food animal production: an economic analysis. *Public Health Reports* 122(1):79-87.
- ⁸³ Committee on Drug Use in Food Animals, Panel on Animal Health, Food Safety, and Public Health, National Research Council. 1999. Costs of eliminating subtherapeutic use of antibiotics. In: *The Use of Drugs in Food Animals: Benefits and Risks* (Washington, DC: National Academy Press, p. 179). <http://books.nap.edu/openbook.php?isbn=0309054346&page=179>. Accessed November 14, 2008.
- ⁸⁴ National Institutes of Health, National Institute of Allergy and Infectious Diseases. 1999. Emerging and re-emerging infectious diseases. 1999. http://science.education.nih.gov/supplements/nih1/diseases/activities/activity5_vrsa-database.htm. Accessed November 14, 2008.
- ⁸⁵ Infectious Diseases Society of America. 2007. Facts about antibiotic resistance. www.idsociety.org/Content.aspx?id=5650. Accessed November 14, 2008.
- ⁸⁶ Food and Agriculture Organization of the United Nations. 2008. FAOSTAT. <http://faostat.fao.org/>. Accessed November 14, 2008.
- ⁸⁷ Wegener HC. 2006. Risk management for the limitation of antibiotic resistance—experience of Denmark. *International Journal of Medical Microbiology* 296(Suppl 41):11-3.
- ⁸⁸ Graham JP, Boland JJ, and Silbergeld E. 2007. Growth promoting antibiotics in food animal production: an economic analysis. *Public Health Reports* 122(1):79-87.
- ⁸⁹ Graham JP, Boland JJ, and Silbergeld E. 2007. Growth promoting antibiotics in food animal production: an economic analysis. *Public Health Reports* 122(1):79-87.
- ⁹⁰ Dritz SS, Tokach MD, Goodband RD, and Nelssen JL. 2002. Effects of administration of antimicrobials in feed on growth rate and feed efficiency of pigs in multisite production systems. *Journal of the American Veterinary Medical Association* 220(11):1690-5.
- ⁹¹ Cassell GH and Mekalanos J. 2001. Development of antimicrobial agents in the era of new and reemerging infectious diseases and increasing antibiotic resistance. *Journal of the American Medical Association* 285(5):601-5.
- ⁹² Nierenberg D. 2005. Happier meals: rethinking the global meat industry. *Worldwatch Paper* 171. www.worldwatch.org/pubs/paper/171/. Accessed November 14, 2008.

The Humane Society of the United States is the nation's largest animal protection organization—backed by 10 million Americans, or one of every 30. For more than a half-century, The HSUS has been fighting for the protection of all animals through advocacy, education, and hands-on programs. Celebrating animals and confronting cruelty. On the Web at humanesociety.org.