How Antibiotic Resistance Happens

What is antibiotic resistance and how do bacteria develop it?

Frequent, low doses of antibiotics that are not strong enough to kill all bacteria encourage some bacteria to develop means of survival, or to become "resistant." Bacteria can develop ways to fight off antibiotics by: preventing antibiotics from reaching their target cells (*e.g.,* changing the permeability of cell walls or pumping the drugs out of the cells); changing the structure of target cells or entirely replacing them; or producing enzymes that destroy antibiotics.

Bacteria may gain resistance by getting copies of resistance genes from other bacteria. Bacteria acquire resistance genes from other bacteria when:

- Microorganisms join together and transfer DNA to each other;
- Free-floating DNA pieces (called plasmids) are picked up, which can carry resistance to a number of antibiotics;
- Small pieces of DNA jump from one DNA molecule to another, and then are incorporated; and
- DNA remnants are scavenged from dead or degraded bacteria.

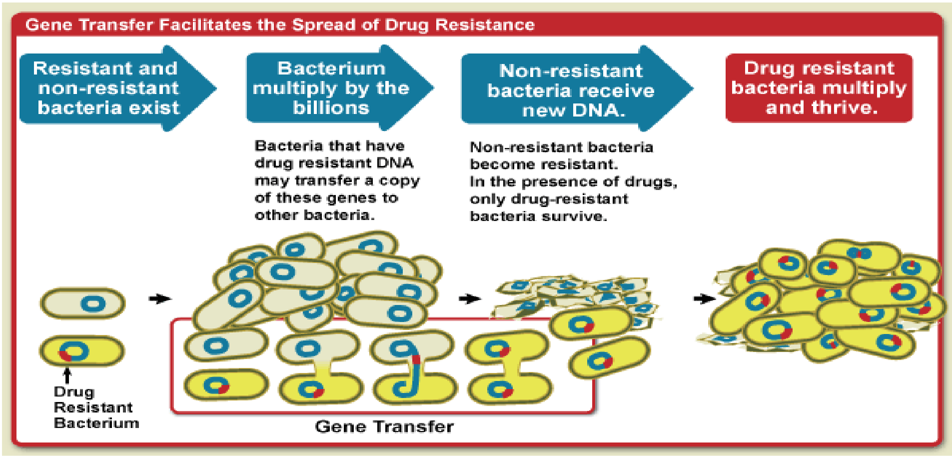
Once a resistance gene is picked up and added to a bacterium's DNA, the bacterium can dominate other bacteria, and pass the resistance gene on to all of its descendants. Resistance is magnified because bacteria multiply rapidly.

Where does the antibiotic resistance problem come from?

Antibiotic resistance will eventually occur because of evolutionary natural selection, but the misuse and overuse of antibiotics is dramatically escalating the process. When antibiotics are used incorrectly in human or animal medicine—for too short a time, or too small a dose, at inadequate strengths, or for the wrong disease—bacteria are not killed and can pass on survival traits to even more bacteria. This results in stronger infections, increased illness and even death.

Increasing resistance also comes from the excessive use of antibiotics, including prolonged treatments of insufficient strength to kill all the bacteria, which occurs commonly on industrial animal farms. Antibiotics are used in cattle, poultry, swine and other food animals not only for disease treatment in individuals, but also to stave off disease in entire herds or flocks living in crowded, unsanitary conditions, as well as for growth promotion and improving "feed efficiency" (*i.e.*, the amount of feed it takes to produce a pound of animal). In fact, up to 70 percent of all antibiotics produced in the U.S. are given to food animals, not people.[1]

According to the World Health Organization, "widespread use of antimicrobials for disease control and growth promotion in animals has been paralleled by an increase in resistance in those bacteria (such as *Salmonella* and *Campylobacter*) that can spread from animals, often through food, to cause infections in humans."[2]



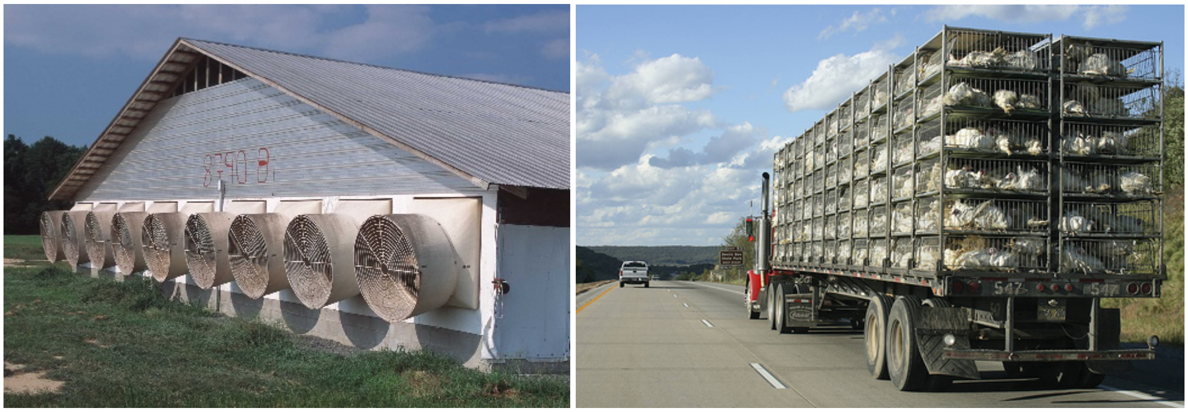
When two bacteria come in contact, they can easily pass along DNA segments containing antibiotic-resistant genes (red segments). (Adapted from the National Institute of Allergy and Infectious Diseases.)

How are people exposed to antibiotic-resistant bacteria from industrial animal farms?
Food animals can shed resistant bacteria in their feces, or on skin in the case of *Staphylococcus* infections. Once there, antibiotic-resistant bacteria in contaminated manure can migrate around a farm, in slaughter and meat processing, into neighboring farms and the environment, and even across long distances. Therefore, once harmful resistant bacteria are generated, they are hard to control.

Manure from factory farms is routinely applied directly to pastures and croplands as fertilizer, sometimes contaminating food crops with antibiotic-resistant bacteria. Runoff from factory farms —made worse after heavy rains—can also carry antibiotic-resistant bacteria into the drinking water supply. (Photos: USDA)

There are several direct routes of human exposure to antibiotic-resistant bacteria that develop in industrial food animal production:

- Improperly handling or consuming inadequately cooked contaminated meat.[3]
- Contact with infected farm workers or meat processors, or perhaps their families, doctors and others with whom they interact.[4]
- Drinking contaminated surface or ground water and eating contaminated crops.[5]
- Contacting air that is vented from concentrated animal housing or is released during animal transport.[6]



Antibiotic-resistant bacteria can become airborne when vented from concentrated animal housing, or even when the animals are trucked to processing plants that are sometimes hundreds of miles away. (Photos: USDA; Flickr.com)

Unfortunately, the risk of exposure to antibiotic-resistant bacteria does not stop there. Because of the ease with which bacteria share resistant genes, strains of resistant bacteria that emerge in food animal production may not be contained and may introduce resistant genes to other bacteria in the broader community. This means the overall problem of antibiotic resistance intensifies over time. In order to contain the problem of antibiotic resistance, all improper uses of antibiotics must be addressed in both people and animals.

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[1] Mellon, Margaret, Charles Benbrook, & Karen Lutz Benbrook. 2001. *Hogging It! Estimates of Antimicrobial Abuse in Livestock.* Cambridge, MA: Union of Concerned Scientists.

[2] World Health Organization. Revised January 2002. Fact Sheet number 194, "Antimicrobial resistance." Available at: http://www.who.int/mediacentre/factsheets/fs194/en/.

[3] U.S. General Accounting Office (GAO). 2004. No. 04-490, *Antibiotic Resistance: Federal Agencies Need to Better Focus Efforts to Address Risk to Humans from Antibiotic Use in Animals.* See also: White, David G. *et al*. 2001. The Isolation of Antibiotic-Resistant Salmonella from Retail Ground Meats. *The New England Journal of Medicine*. 345(16): 1147-1154; Molbak, K. *et al*. 1999. An Outbreak of Multidrug-Resistant, Quinolone-Resistant *Salmonella Enterica* Serotype Typhimurium DT104. *The New England Journal of Medicine*, 341(19): 1420-1425; and Johnson, James R. *et al*. 2006. Similarity between Human and Chicken *Escherichia coli* Isolates in Relation to Ciprofloxacin Resistance Status. *Journal of Infectious Diseases* 194(1): 71-78.

[4] GAO, *op. cit.* See also: Price, Lance B. *et al*. 2007. Elevated Risk of Carrying Gentamicin-Resistant *Escherichia coli* among U.S. Poultry Workers. *Environmental Health Perspectives* 115(12): 1738-1742; and Smith, Tara C. *et al*. 2009. Methicillin-Resistant *Staphylococcus aureus* (MRSA) Strain ST398 Is Present in Midwestern U.S. Swine and Swine Workers. *PLoS ONE* 4(1): 1-6.

[5] GAO, *op. cit.* See also: Chee-Sanford, J. C. *et al*. 2001. Occurrence and Diversity of Tetracycline Resistance Genes in Lagoons and Groundwater Underlying Two Swine Production Facilities. *Applied and Environmental Microbiology* 67(4): 1494-1502; Sapkota, A. R. *et al*. 2005. Antibiotic-Resistant Enterococci and Fecal Indicators in Surface Water and Groundwater Impacted by a Concentrated Swine Feeding Operation. *Environmental Health Perspectives* 115(7): 1041-1045; and Gibbs, Shawn G. *et al*. 2005. Isolation of Antibiotic-Resistant Bacteria from the Air Plume Downwind of a Swine Confined or Concentrated Animal Feeding Operation. *Environmental Health Perspectives* 114(7): 1032-1037.

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