

Microbes: What They Do & How Antibiotics Change Them

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Microorganisms — bacteria, archaea, fungi, algae, viruses and protists — are often easy to overlook. For the most part (except fungal fruiting bodies seen as mushrooms) we can't see microbes. The effects of microbes we feel are usually associated with an illness. Most people know that bacteria and viruses can act as “germs” and cause disease. Because of this it seems perfectly acceptable to try to wipe all of the germs out of our environment by using antibacterial agents (found in everything from hand soap to sweat socks) and antibiotics. However, our use of antibiotics and antibacterial agents is changing the microbes in our environment, making the germs tougher to beat and eliminating some beneficial microbes.

Beneficial functions of microorganisms

Microorganisms are essential to our very existence. They are ubiquitous, found in common environments such as soil, water, and air as well as exotic locales as diverse as deep sea hydrothermal vents and soda lime lakes. In these natural environments microorganisms have very specific jobs. They are responsible for recycling nutrients in our soil and purifying our water. We also use microorganisms in constructed environments to serve our own functions.

Sources of antibiotics in the environment

In spite of all of the benefits of having a healthy microbial population, antibiotics and antibacterial agents are added to the environment at a rate of over a million pounds per week. There are several routes of entry of antimicrobial agents into the environment. Studies have shown that introduction by these routes has changed the antibiotic susceptibility of the microbes in those environments and/or changed the predominant microbes.

- **Sewage.** The antibiotics that we take in are not all processed by our bodies. Some of them are expelled as waste and wind up in our waste water treatment plants. Of bacteria isolated from sludge remaining after wastewater treatment at one plant, 46.4% were resistant to multiple antibiotics. Sewage from hospitals and pharmaceutical plants has been shown to contribute to antibiotic resistance in treatment plants. Rivers contaminated with urban effluent and agricultural runoff have also been shown to have greater antibiotic resistant bacterial populations than areas upstream of the contamination source. Antibiotic resistance in streams is also indirectly selected for by an increase in industrial wastes containing heavy metals.
- **Medical waste.** The dispensing of antibiotics in a medical facility inevitably leads to waste. Discharge from hospitals has been shown to cause an increase in bacterial populations resistant to certain antibiotics such as oxytetracycline.
- **Production.** Antibiotic sales total more than \$8 billion worldwide each year. That is 50 million pounds produced each year, 25 million pounds of which are prescribed for human use. Discharge of wastewater from pharmaceutical plant has been associated with an increase in the prevalence of single- and multiple-antibiotic resistance in indicator organisms.
- **Household products.** Over 700 “antibacterial” household products have been introduced in the past

five years. These include such items as sweat socks, toothpastes, kitchen plastics, cement and paints. The more common antibacterial ingredients in these formulations are triclosan, quaternary ammonium compounds, alcohol, and bleach. Microbes resistant to each of these compounds have been documented in nature and in some human pathogens. These products wind up in the sewage or landfill after being used in our households.

- **Sprayed on crops.** About 300,000 pounds of antibiotics are used in plant production each year. They are sprayed on high-value crops such as fruit trees to prevent bacterial infections. This can select for resistant bacteria on our crops. Not all of the spray remains on the fruit. Most of the antibiotics are washed into the soil and eventually end up in the ground water.
- **Animal production.** Antibiotics are commonly added at subtherapeutic levels to animal feeds as growth promoters. They are also added to fishery waters. About 24 million pounds of antibiotics are fed to animals every year. Due to this practice antibiotic resistance in foods has become a health concern. Bacteria such as drug resistant *Salmonella typhimurium*, *Escherichia coli* and Enterococcus have increased clinically as animal antibiotic use has risen. It is also possible that our normal gut microbiota have gained antibiotic resistance from antibiotic-exposed food animals. A popular theory is that vancomycin resistant strains of the bacterium Enterococcus (VRE), a major cause of postsurgical infections, have arisen in Europe due to the use of the antibiotic avoparcin as an animal growth promoter. At least one study, however, shows that in minced beef and pork, VRE occurs very rarely. The use of oxytetracycline in aquaculture has been shown to cause a seasonal shift in bacterial species towards Enterobacteriaceae and is associated with increased antibiotic resistance.

Mechanisms of spread of antibiotic resistance

Antibiotics do not, in themselves, cause resistance. Instead, they allow naturally resistant variants within a population to survive and reproduce while those individuals without the resistance factor die. Once in a bacterial population, antibiotic resistance can spread rapidly. Even unrelated bacteria can gain resistance from their neighbors in a phenomenon called horizontal gene transfer. Resistance to antibiotics is encoded in DNA, the genetic blueprint for life. Bacteria are able to exchange DNA, especially in the form of plasmids (small, self-replicating circles of DNA) and pass resistance very rapidly.

- **Conjugation.** Bacteria can fuse and exchange plasmids and sometimes chromosome fragments. Increase in mobilizing plasmids has been associated with use of antibiotics in swine husbandry. These plasmids have a broad host range and are able to cross genus lines during transfer.
- **Transfection.** Viruses can infect bacteria and fungi, passing along genes from one infected organism to the next. These genes sometimes encode resistance factors. The use of antibiotic growth promoters in animal husbandry may increase the amount of free phage in intestines and may contribute to the spread of antibiotic resistance.
- **Transformation.** When a bacterium lyses in its environment, any other actively-growing bacteria in that vicinity can pick up its DNA. This is another mechanism of resistance spread, since plasmids (including resistance or R plasmids) are more easily used by the recipient bacterium than chromosomal material.

Microbial populations have been shown to change due to exposure to antibiotics and antibacterial

agents. We are seeing a rise in antibiotic resistance all around the world. Some diseases that were previously susceptible to a variety of antibiotics now are untreatable. According to the Center for Disease Control (CDC), approximately 70 percent of infections that people get while hospitalized are now resistant to at least one antibiotic. Resistance to antibiotics is rapidly outpacing our ability to synthesize new drugs. While only a very small proportion of bacteria in our lives can potentially harm us, we are losing our arsenal to treat these rare infections.

Curbing spread of antibiotic resistance

Antibiotic resistance is inevitable. However, there are a few things that we, as consumers, can do to control the spread of antibiotic resistance.

- **Do not seek antibiotics for the treatment of viral infections** such as the common cold, sore throat, bronchitis, or flu. Antibiotics have no effect on viral diseases. Taking antibiotics improperly simply leads to more antibiotics in the sewage and a buildup of antibiotic resistant bacteria in your microbiota.
- **Take the full course of antibiotics when they are prescribed.** Stopping when you feel better means that some bacteria in your body were exposed to only small doses of the antibiotic and have survived. They are now resistant to small amounts of the antibiotic. The next time you get an infection they will not be so easily killed.
- **Avoid unnecessary antibacterial household products.** We need the bacteria that surround us, and it is possible that trying to kill them is causing harm. By introducing antibacterial products into the landfills and sewage we are ensuring that only the microbes that are resistant to these products survive. Research is underway to determine if we are selecting for resistant bacterial populations causing antibacterial agents, like antibiotics, to lose their effectiveness or disrupt the effectiveness of the wastewater treatment plants or nutrient cycling in the soil. Use antibacterial hand soaps only when dealing with ill and immunocompromised individuals.
- **Wash your hands.** The best way to stop the spread of any bacterial infection is through simple hygiene measures. Washing hands in warm soapy water for at least 20 seconds is enough to eliminate most of the potential pathogens. Also be sure to wash all fruits and vegetables well before eating them.

Conclusion

Microbes are an essential part of all life on earth. The addition of antibiotics and antibacterial compounds is changing the microbial populations of the soil, water, and our own microbiota. Recognizing the numerous invaluable functions of microbes should decrease the germophobia prevalent in Western societies.