Bacteria have many characteristics that allow them to evolve resistance to whatever antibiotics we throw their way — short generation times, high mutation rates, and horizontal transfer — and current agricultural practices (in particular, the heavy use of antibiotics in livestock) seem destined to speed this process even further. In the U.S., around 80% of antibiotics are destined for farm animals, not for treating human disease. The majority of those animal antibiotics are used preventatively and to promote faster growth and speed meat production, not to treat sick individuals. Unfortunately, this approach also encourages the evolution and proliferation of antibiotic resistant strains on factory farms. So, it should come as no surprise that a large percentage of supermarket meat carries antibiotic resistant bugs!

Clearly, the ubiquity of antibiotic resistant bacteria in livestock has implications far beyond highlighting the need to cook meat thoroughly. It suggests that, lurking in farm animals, is a vast pool of dangerous resistance genes that could easily make their way out of the bacteria in which they currently reside and into strains that would represent an even more significant human health threat. We have many lines of evidence suggesting that horizontal transfer of genes, including resistance genes, is commonplace among bacteria. What we have not had is a major outbreak of an antibiotic resistant infection that has been definitively linked to resistance from bacteria inhabiting livestock — yet. If the American Medical Association, the World Health Organization, and the National Academy of Sciences have their way, we may be able to avoid that fate, at least for certain antibiotics. These groups have all signed on to support new legislation that would prevent widespread use of certain antibiotics on livestock, helping to protect the effectiveness of these drugs in humans.

Background: Watch: “Superbugs” http://time.com/4767683/bacteria-antibiotic-resistance-superbugs/ (in class or linked on class blog)
Read the article above

1. **Background:**
   a. **Explain** how mutation and horizontal transfer affect the genetic variation in a bacterial population

   b. **List** three things that antibiotics do to fight bacteria:

   c. **List** two adaptations found in resistant bacteria:

2. **Claim:** Natural Selection causes bacteria to adapt to changing environmental conditions

   a. **Define** Natural Selection:

   b. **Evidence:** **Describe** observations do we have that natural selection is the mechanism for bacteria changing?
Antibiotic resistant bacteria at the meat counter

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The pork chops you buy in the supermarket neatly packaged in plastic and styrofoam may look completely sterile, but are, in fact, likely to be contaminated with disease-causing bacteria — and not with just any old bugs, but with hard-to-treat, antibiotic resistant strains. In a recently published study, researchers with the National Antimicrobial Resistance Monitoring System bought meat from a wide sampling of chain grocery stores across the country and analyzed the bacteria on the meat. Resistant microbes were found in 81% of ground turkey samples, 69% of pork chops, 55% of ground beef samples, and 39% of chicken parts. Of course, thoroughly cooking the meat will kill the germs, but if the meat is undercooked or contaminates other food with its bacteria — perhaps via a shared cutting board — the result could be an infection that can’t be cured with common medications. Such infections are a serious health concern — a strain of antibiotic resistant staph was recently estimated to cause nearly 20,000 deaths per year in the U.S. — and the problem seems to be getting worse. An evolutionary perspective helps us understand how antibiotic resistance arises in the first place and why the prevalence of resistant bugs in livestock has health professionals and scientists worried.

Where’s the evolution?

It should be no surprise that antibiotic resistant bacteria are the products of evolution via natural selection: as bacteria reproduce, small, random errors (i.e., mutations) occur as their DNA is copied. Just by chance, some of those mutations may help their bearers survive and reproduce better and so will increase in frequency in the bacterial population. Other mutations may be detrimental and will be weeded out of the population. Still others may have no impact at all to the bacterium’s fitness (i.e., neutral mutations) and will change in frequency through genetic drift. When antibiotics flood the environment of the bacteria, individuals that happen to carry random mutations that allow them to survive and reproduce despite the drug will be favored. Eventually, the entire lineage of bacteria may carry genes that confer antibiotic resistance.

This process seems to be inevitable. If a bacterial lineage is consistently exposed to a particular antibiotic, it will eventually evolve resistance to that drug, and this will occur in the soil, in livestock, in the human body — wherever bacteria are exposed to antibiotics. This same basic process is responsible for the evolution of advantageous traits in familiar organisms, like a hawk’s keen eyesight or a polar bear’s insulating fur. However, bacteria have a leg up on birds and bears when it comes to evolution. Most species rely on mutations somewhere in their historical lineage for their genetic variation — that is, an improved ability to spot prey will evolve in a lineage of hawks only if mutations conferring keener sight occurred somewhere in the hawk lineage and were then passed down to the generation of hawks experiencing natural selection. Bacteria, on the other hand, get their genetic variation both from their ancestral lineage and through a process known as horizontal transfer.

In horizontal transfer, organisms share genetic material with one another directly, as opposed to passing genetic material only to their offspring. In this way, genes from distantly related lineages of bacteria can wind up in the same individual. A gene version that first arose in Escherichia coli could easily be passed on to Salmonella.

Horizontal transfer represents a special danger when it comes to the evolution of resistance because, through gene sharing, antibiotic resistance genes that evolve and become common in one lineage of bacteria that is exposed to a particular antibiotic can be passed to distantly related bacterial lineages. In other words, a bacterial lineage can evolve resistance to a particular antibiotic even if its ancestors never carried a mutation that conferred resistance to that drug. With all this genetic variation being shared, antibiotic resistant bacterial strains can evolve quickly. Furthermore, different antibiotics often have similar modes of action (e.g., amoxicillin and methicillin both work by preventing bacteria from forming cell walls), so resistance to one drug often means partial resistance to a host of other medications. To make matters even worse, bacteria often transfer multiple genes for resistance to different antibiotics on the same piece of DNA. Since the genes are physically attached to one another, selecting for one of those resistance genes lets the others hitchhike to high frequency. So exposing a bacterial population to say, streptomycin, may also unintentionally favor the evolution of a strain that resists many other antibiotics as well — making for a particularly hard-to-cure infection.