**Antibiotic Resistance: Causes and Impacts**

In this chapter, we will discuss antibiotic resistance, what causes it, why it is dangerous, and what we can do about it.

**Background**

 Microbes, specifically bacteria, are living organisms that are a part of our everyday life. There is an estimated 39 trillion bacteria cells living on and in your body at any given time, that’s 9 trillion more than the average human cells that make up your body! Most of these bacteria are “good” bacteria, and contribute to a healthy gut, as well as other organs such as your skin. Many “good” bacteria actually help prevent disease from “bad” or pathogenic bacteria found in and on your body, by competing for nutrients and keeping things in check. Fun Fact: this is why it is recommended by doctors to eat yogurt and other foods fermented with “good” bacteria (such as kefir or kimchi) while taking antibiotics, so that you can maintain a healthy number of beneficial bacteria after the course of antibiotics is taken. Bacteria and microbes are constantly evolving, and are able to adapt to their environments to continue to thrive in harsh conditions, and when something inhibits growth, such as an antibiotic, genetic changes can occur to enable the bacteria to survive. This is where antibiotic resistance occurs. This resistance can occur in several ways that will be outlined later in the chapter.

**What Causes Antibiotic Resistance in Bacteria?**

Inappropriate use, agriculture, and misdiagnosis are some of the major factors that cause antibiotic resistance. Some of the main causes of antibiotic resistance are at the medical level, where people are misdiagnosed with infections they do not have, or are prescribed antibiotics that are sub-optimal for treatment of a specific infection. Another common cause is that doctors often prescribe patients antibiotics when they do not need them, for example, when they have a virus. When antibiotics are given to patients inappropriately, this allows the bacteria in the body to undergo the genetic changes that cause antibiotic resistance. These changes are outlined in the section below. Another cause for antibiotic resistance is when patients do not take the full course of antibiotics prescribed. Patients often stop taking antibiotics prematurely because they “feel better,” but unfortunately just because you feel better does not mean all of the pathogenic bacteria have been killed. This allows the surviving bacteria to undergo genetic changes that lead to antibiotic resistance, and then they replicate and spread. The final major contributor to antibiotic resistance is agricultural use. It has previously—and in some cases still is—common practice to administer antibiotics to healthy livestock to prevent infection. This overprescribing of antibiotics not only allows resistance to occur, but also leaves traces of antibiotics in the meat and byproducts of livestock production which is then consumed by humans. Some ways to combat these major contributors to antibiotic resistance is outline in the final section of this chapter.

**How does antibiotic resistance occur at the microscopic level?**

Selective Pressure

The influence exerted on bacteria by antibiotics promotes one group of organisms with superior genes to be selected over others. This is called selective pressure, and causes susceptible bacteria to be killed and allows antibiotic resistant bacteria to survive and multiply. Selective pressure occurs when bacteria that are already resistant to an antibiotic replicate and their progeny become the dominant type throughout the bacterial population.

Mutation

A mutation is a permanent alteration to a DNA sequence that makes a gene. When cells multiply, two identical copies of DNA are made through the processes of replication, during this process mistakes can be made resulting in a mutation. When mutations occur during replication, they can make new genes that allow for antibiotic resistance to be acquired by the bacteria, and these new genes are passed on to the population that replicates from these mutated bacteria, resulting in a fully resistant generation of bacteria.

Horizontal Gene Transfer

Horizontal gene transfer is the transmission of DNA between different genomes. Some bacteria possess the ability to transfer copies of their genes that select for antibiotic resistance to other, non-resistant bacteria. This allows the non-resistant bacteria to incorporate that gene into their genome and become resistant to a specific antibiotic. The newly acquired DNA is incorporated into the genome of the recipient though either recombination or insertion. Recombination is the regrouping of genes so that new DNA segments (that are homologous) are edited and combined into the genome. Insertion occurs with the new DNA shares no homology with the existing DNA, so the DNA is embedded between existing genes in the genome.

**What Issues Arise from Antibiotic Resistance?**

There are currently 18 bacterium classified as current antibiotic resistant threats in the United States, 3 of which are at a threat level of concerning, and 12 of which are at a threat level of serious. A minimum estimated 37,000 people die from infections by antibiotic resistance bacteria annually.

When opportunistic pathogens develop antibiotic resistance, such as the *Staphylococcus aureus* that cause MRSA (methicillin-resistant Staphylococcus aureus), seemingly common and treatable infections become life threatening. Treating these resistant bacteria becomes a challenge that has caused loss of limbs, and even loss of life because of the difficulties that arise when attempting to treat what may have started as just a simple infected cut or scrape. *Staphylococcus aureu*s is an opportunistic pathogen that can be found on nearly everyone’s skin, but does not usually cause infection in healthy individuals. However, when this bacteria does cause infection, it was regularly treated with a methicillin based antibiotic. Through the processes mentioned earlier, such as inappropriate use of the antibiotic, the *Staphylococcus aureus* developed resistance to this family of antibiotics, and thus rendered the treatment ineffective. The development of this resistance caused the infections to have slower treatment times causing complications such as amputation, and in the worst cases, was unable to be treated in time, causing sepsis, and subsequently death. The mechanism of antibiotic resistance in Staphylococcus aureus is not unlike the other bacterium that have developed similar resistances, and the outcomes for more difficult-to-treat bacterium are even more grave.

**What Can We Do to Combat Antibiotic Resistance?**

Antibiotic misuse and overused has accelerated antibiotic resistance, as well as inadequate infection prevention and control. Steps can be taken at all levels of society to help alleviate the growing issue of antibiotic resistance. Individuals can take steps by only using antibiotics when they are prescribed by a health care provider, completing the full course prescribed, and preventing infection by regularly washing hands and properly preparing food. Healthcare providers can prevent and control the spread of antibiotic resistance by educating individuals about antibiotic resistance and the dangers of misusing antibiotics, furthermore, informing the patients of the importance of taking antibiotics correctly and finishing the full course prescribed. Additionally, health care providers should insure that antibiotics are only prescribed when needed, according to current guidelines. Lastly, antibiotics should never be given for growth promotion or disease prevention in healthy animals in the agricultural industry.

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