Antibiotic Overuse: The History, Consequences, and Possible Solutions

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Abstract

Antibiotic overuse has become alarmingly accepted in the developed world. This overuse is leading to drug resistance in microbes, resulting in bacterial infections that are impossible to treat. Steps must be taken to reverse the damage that has already been done and prevent further resistance from developing. This thesis will examine the context and societal situations that led to this acceptance of antibiotic overuse and misuse seen in both health care professionals and the public, the biochemical and genetic pathways that allow a microbe to develop drug resistance, the various methods that have been suggested by experts to prevent and reverse this epidemic, the consequences that could follow if this trend of antibiotic overuse is allowed to continue, and how antibiotics fit into the biblical Christian worldview. The situation has not yet progressed to a point of no return. This thesis will propose several potential solutions to this issue.

Antibiotic Overuse: The History, Consequences, and Potential Solutions

Dr. Alexander Fleming discovered the first antibiotic, penicillin, in 1941. The drug was hailed as a miracle, and it was soon thought by most of the world that the end of all disease was in sight. Dr. Fleming, however, could see a much darker future than that being predicted and hoped for by the general public and health professionals alike. In his Nobel lecture of 1945, Dr. Fleming warned, "The time may come when penicillin can be bought by anyone in the shops. Then there is the danger that the ignorant man may easily under dose himself and by exposing his microbes to non-lethal quantities of the drug make them resistant" (Barrett, 2014, p. 26). The United States has not yet reached the point of antibiotics being available to any desiring person over the counter with no prescription, but the country is showing signs that it is coming dangerously close. A future in which antibiotics are sold in a fashion similar to that of Tylenol or Aspirin is not inconceivable. In fact, many believe that a freer marker for antibiotics would be a quite positive thing. Many physicians and other health care professionals prescribe antibiotics with little to no caution. It has become expected practice to prescribe antibiotics for common and minor bacterial infections such as *Streptococcus pyogenes*, the bacteria responsible for strep throat, which would normally be eliminated in approximately ten days by a healthy immune system. Antibiotic overuse has become alarmingly accepted in the developed world. This misuse is leading to drug resistance in microbes, resulting in bacteria that are impossible to treat with currently available antimicrobial medications. Steps must be taken to reverse the damage that has already been done and prevent further resistance from developing. This thesis will examine the context and societal situations that led to this acceptance of antibiotic overuse and seeming ignorance towards the issue

seen in both health care professionals and the public, the biochemical and genetic pathways that allow a microbe to develop drug resistance, the various methods that have been suggested by experts to prevent and reverse this epidemic, the consequences that could follow if this trend of antibiotic overuse is allowed to continue, and how antibiotics fit into the biblical Christian worldview. The situation has not yet progressed to a point of no return. This thesis will propose several solutions to this growing issue.

Context Leading to Antibiotic Crisis

Brief History of Antibiotics

Louis Pasteur is remembered as the father of microbiology. He contended that if the germ for each malady could be isolated and a treatment devised to kill the germ, virtually all disease could someday be eradicated (Schmidt, 2009). This would be a promising future indeed. His view, prior to the development of antibiotics, was a shocking one to the medical society. The world had been dominated for all of past human history, at least subsequent to the Fall and the introduction of pathogenesis into nature, by microbes. Infectious disease was the number one cause of death world-wide prior to antibiotics. Childbirth and surgery resulted in debilitating and sometimes deadly infections in almost half of the cases. A simple scratch on a child's knee could lead to serious, life-threatening infection and illness. Pasteur's suggestion of a future in which these disease-causing bacteria could be once and for all done away with was readily accepted and hoped for. In his final years of life, Pasteur began to consider that his theory could be incorrect. He began to teach the importance of focusing on the "terrain", or the overall health of the human host, rather than eradicating the microbial intruder, as the most important factor in preventing and treating infectious disease (Schmidt, 2009). Prior

to his death, Pasteur came to the conclusion that a plethora of factors, including diet, nutrition, stress, heredity, environment, and mental condition, have a profound effect on the body's resistance to microbes (Levvy, 2002). His beliefs passed largely by the wayside, only resurfacing and being considered anew in today's modern antibiotic crisis.

Antibiotics are generally a new phenomenon. They are a surprisingly recent addition to the practice of medicine. Penicillin, the first antibiotic to be developed for use in humans, was discovered by Dr. Alexander Fleming in 1928 by fortunate accident (Lax, 2004). The discovery of penicillin took medicine "out of the dark ages and into the light" (McKenna, 2014, p. 3). God created all things in his magnificent wisdom. He left us many wonderful things to discover that enhance and improve our lives. It is the belief of many that God placed antimicrobial substances in creation even prior to the Fall of man and introduction of pathogenicity (Keen, 2012). Antibiotics are included in this. It is the strong belief of many scientists who adhere to the Christian faith that God orchestrated the events of Dr. Fleming's life to lead him to this exact discovery. Drs. Florey and Chain went on to further Dr. Fleming's research and turn the antimicrobial mold that he had discovered into something suitable for use in the medical field (Lax, 2004). Penicillin was first used on a 43-year-old police man named Albert Alexander. Alexander was on the brink of death when the drug was first administered to him. After five days of treatment with penicillin, Alexander had begun to improve dramatically. Unfortunately, there was only a tiny amount of penicillin available for use, and it ran out before Mr. Alexander was completely healed (Lax, 2004). He passed away, but the knowledge gained about the power of penicillin persisted. Penicillin was believed to be a miracle drug, saving the lives of thousands of soldiers in World War II and improving the quality

of life for the public. The discovery, manufacture, and distribution of penicillin pushed the world fully into what is known as the Antibiotic Era (Levy, 2002). By the 1950s, it was suddenly possible to treat a whole host of infections that were previously seen as unconquerable. Doctors were so excited by this development that they began to speak about a time in the future when death from infection would be a darkly remembered thing of the past (McKenna, 2014). Seemingly minor infections were no longer possible death sentences. Even some of the more serious infections could now be treated and cured using antibiotic medication. Antibiotic development continued and increased throughout the following decades. Countless antibiotics are now available for medical use. Over fifty variations of penicillin, seventy cephalosporins, twelve tetracyclines, eight aminoglycosides, one monobactam, three carbapenems, nine macrolides, two streptogramins, and three dihydrofolate reductase inhibitors were all available in the early 1990s for the treatment of bacterial disease (Neu, 1992). In the years since, even more antibiotics have been developed and made available. Some are derivatives of penicillin, others are synthetic (Keen, 2012). Today, there are well over 100 classes of antibiotics, though most fall into the category of penicillin derivatives (Shallcross, 2014). Antibiotics work by inhibiting bacterial cell wall synthesis, protein synthesis, and/or DNA replication (McKenna, 2012). The various classes of antibiotics work in different manners. All of them are focused on attacking either the bacterium's ability to keep itself alive or its ability to reproduce and propagate within the human host. Breaking down the cell wall will cause the bacterial cell to lyse and its contents to spill. Naturally, the cell will not be able to survive with a breach in its defense. Issues with the stability of the cell wall will also prevent the bacterial cell from being able to grow. Inhibiting protein synthesis is

extremely detrimental to the bacteria because proteins are responsible for nearly every function the cell performs to sustain itself. Interfering with DNA replication will not kill the cell directly, but it will prevent the cell from reproducing (Barrett, 2014). This allows time for the body's immune system to mount a response without being overwhelmed by generations of new bacteria. The plethora of antibiotics now available are widely and readily prescribed by medical providers. All are being used in an alarmingly loose way that is fueling and contributing to the modern day antibiotic crisis. This crisis is a result of many factors: pharmaceutical companies, prescribers, patients, agriculture, and the genetic abilities of bacteria.

Role of Pharmaceutical Companies

Many factors have led up to and continue to contribute to the overuse of antibiotics in modern day society. Pharmaceutical companies have played a colossal role in the antibiotic crisis. They are heavily profit driven and operate with what could at times be described as shady and questionable tactics. Between 1988 and 1992, the FDA approved an average of 3 new antibiotics each year (Schmidt, 2009) Antibiotics were plentiful and profitable during these years. Guidelines on development were not quite so strict prior to the 2000s. Animal testing laws in particular were much easier to navigate around (Shallcross, 2014). Since 2003, only one new antibiotic per year on average has been approved by the FDA for medical treatment (Schmidt, 2009). The largest names in pharmaceuticals, including Wyeth, Eli Lilly, Procter and Gamble, Roche, Abbott Laboratories, and Aventis have either largely reduced their antibiotic research and development or terminated their antibiotic research entirely (Schmidt, 2009). It is simply not as profitable to focus on antibiotics as other areas of research. These companies have

shifted their research and development focus to medications with wider markets and higher profit margins. Drugs that are used in the treatment of chronic conditions are of particular interest to big pharmaceutical companies. Antibiotics are much more difficult and expensive to manufacture than medications for conditions such as diabetes, high cholesterol, depression, and arthritis. Antibiotics are far less profitable than other so called "maintenance medications". Antibiotics are only used for a short duration and will only be utilized periodically during a person's lifetime. It is understandably difficult to make any money on the development of a medication that will only be used for approximately ten days at a time every other year, especially when antibiotics are so hard to find, develop, and test. To make a long story short, there is a lot more money to be made from so called "blockbuster" drugs than from antibiotics that will only be used periodically and for a short duration by patients (Schmidt, 2009). Pharmaceutical companies are very invested in the antibiotics that have already been produced. They desire to keep making money off of the work they have already done (McKenna, 2012). A study published in the PLoS medical journal found that pharmaceutical companies spent roughly 1.6 billion dollars in 1998 to promote antibiotics to customers, hospitals, doctor's offices, and pharmacies (Huttner, 2009). This money could easily be spent in the pursuit of new antibiotics or on safe antibiotic usage campaigns. Sadly, it is being used only to market and encourage the further use of already well-established antibiotics. Pharmaceutical companies have little incentive to investigate and produce new antimicrobial medications. They can make considerably higher profits by developing drugs for other conditions, especially those that are widespread and chronic such as diabetes and high blood pressure.

Role of Physicians

Another contributing factor in the overuse of antibiotics is the growing trend of physicians and other practitioners over-prescribing antibiotics. Antibiotic use is increasing substantially worldwide, though it is increasing to the largest degree in the United States and other highly developed countries (Ackerman, 2012). Antibiotic over-prescription is understood to be very expensive and known to contribute to the growing resistance of bacteria (Arason, 2010). Despite these well-known and alarming facts, antibiotics are being vastly over-used and misused. Antibiotics are often prescribed for viral illnesses that will not be helped by antibiotic medication. Upper respiratory infections are the number one reason a non-hospital provider will prescribe antibiotics to a patient (Kleinman, 2005). However, antibiotics provide very little benefit for the majority of respiratory tract infections that present to primary care facilities. Upper respiratory infections are typically self-limiting, meaning the body's immune system can clear them out within ten days or so with no intervening medical treatment. Prescribing antibiotics for self-limiting illnesses is perhaps the main reason for the emergence of antibiotic-resistant bacteria seen widespread in the community setting (Arason, 2010). It is perplexing to consider the reasons physicians, who are typically very highly educated individuals, choose to prescribe medications that will do more harm than good for the patient and society as a whole in the long run. This frightening trend has its roots in many factors. Despite their reasons, the truth remains that antibiotic prescription is very seldom based on clinical factors alone (Ackerman, 2012). It has been suggested that antibiotic over-prescribing can be correlated with the prescriber's individual personality and environment. Clinician characteristics that have been linked to unnecessary prescribing

include years of practice, medical specialty, perceived patient expectations, and desire to please the patient (Ackerman, 2012). General practitioners prescribe somewhere around ninety percent of the antibiotics prescribed in the United States for a given year and more than half of these are prescribed to treat respiratory tract infections (Llor, 2014). Statistics are very close to these numbers for most highly developed European countries as well (Huttner, 2009). Urinary tract infections are the second most common malady for which antibiotics are typically prescribed. It is estimated that more than fifty percent of patients who present to a primary care facility with symptoms of a urinary tract infection are treated right away with antibiotics, despite the fact that urinary tract infections are incredibly self-limiting and pose a very small threat to an individual's overall health and wellbeing (Mainou, 2000). Treating urinary tract infections with antibiotics before performing the necessary lab work is not only irresponsible from a microbial resistance point of view; it is also quite costly and ineffective in treating the illness. The patient may be given peace of mind knowing that he or she was prescribed something tangible, but the benefit will go no further. The harm done by prescribing antibiotics for urinary tract infections far outweighs the good it will do to the patient. The majority of the responsibility for the ineffective and irresponsible prescribing of antibiotics lies with the prescribers, whether they be physicians, physician assistants, or other medical faculty (McKenna, 2012). However, the patient also bears a portion of the blame and responsibility. It is indeed patient expectations and presuppositions that make doctors feel bullied or forced into prescribing antibiotics either "just in case" or to please a difficult patient who will not be satisfied unless they leave with a prescription.

A study was recently performed in Iceland to examine how often and in what contexts medical practitioners, specifically family and general practitioners, prescribe antibiotic medications to patients who present with no clear or definite signs of bacterial infection. Arason calls this prescribing method "non-pharmacological prescriptions of antibiotics" (Arason, 2010, p. 113). The study found that the primary reasons doctors would prescribe antimicrobial drugs to a patient with a non-definite bacterial illness are all related to the ever changing doctor-patient relationship. In the region studied, the reason for this fluctuation in doctor-patient relations was supposed to be the lack of continuity in medical care that most patients sought out. Pressure from patients in a stressful society, the physician's heavy work pressure, the prescriber's own personality, any supplemental income or prescribing incentives they may be receiving from pharmaceutical companies, and the physician's lack of confidence or uncertainty in their diagnostic abilities were the main factors that resulted in a situation in which antibiotic prescriptions were prescribed as a kind of coping strategy for an uncomfortable situation with a patient (Arason, 2010). A European study recently surveyed one thousand general practitioners about their prescribing habits and practices. Fifty-five percent of the general practitioners admitted to feeling under intense pressure from patients to prescribe antibiotics, even if the practitioner insisted and explained to them that the antibiotic was unnecessary and would be ineffective. Forty-four percent of the general practitioners further admitted to prescribing antibiotics to a difficult patient just to get them to leave the office (Llor, 2014). It is not difficult to place oneself in the shoes of a prescriber facing pressure from all sides. While this plight of doctors is perfectly understandable, it is by no means excusable.

The over-prescription of antibiotic medication is particularly prevalent among pediatric patients. A study in the *Scandanavian Journal of Primary Health Care* found that, in the region studied, children under the age of seven consumed nearly twenty percent of the total antibiotic medication sold, though they comprised only about 10% of the total family care office visits. Over half of these patients were prescribed antibiotics due to ear infections, which are seldom caused by bacterial infection. They are almost always of a viral nature (Arason, 2010). A correlation was found between the amount of antibiotics an individual child consumed and the risk of that patient being a carrier of antibiotic resistant microbes, specifically *penicillin non-susceptible pneumococci*, in the weeks following the medical treatment (Arason, 2010). Pediatric ear infections are some of the most common illnesses that prescribers will prescribe an antibiotic to treat (Lashley, 2002). Upper respiratory tract infections are the leading cause of antibiotic overprescribing in the outpatient setting, both for pediatric and adult patients (Huttner, 2009). Another study done in Sweden and published by the same journal found that after the implementation of more thorough diagnostic techniques, fewer patients were being diagnosed with bacterial upper respiratory infections. Shockingly, the proportion of patients who were prescribed an antibiotic did not decrease as may be expected. The proportion of patients who were prescribed an antibiotic actually increased over the time period studied (Arason, 2010).This study shows fairly definitively that clinical factors such as lab workups are very low on the list of reasons a prescriber would prescribe antibiotic medication to a patient. A cause that may be a contributor to unnecessary antibiotic prescribing is the fact that antibiotic over-prescription has been shown to increase the likelihood that patients will return to a certain provider or office (Llor, 2014).

Knowing that one can go into a doctor's office and leave with definitive treatment, regardless of whether or not that treatment is appropriate for one's individual case and condition, will increase the likelihood of the individual bringing their business back to that provider. Patient loyalty is likely a contributing factor to the antibiotic crisis.

Role of Patient

Patients have become far more demanding and entitled in recent decades. They often believe that if they leave a doctor's office or treatment center without an antibiotic or other tangible and definitive treatment, they are being short changed or cheated in some way. Patients see prescribers as lazy and uncaring if they choose not to prescribe a medication for the individual's malady (Mainou, 2000). Misconceptions and presuppositions abound within the public's belief as it pertains to antibiotics. A study done in Europe looked at what the general public believes about antibiotics and their effectiveness. The study found that about half of the patients surveyed believed that antibiotics were fully effective in treating viruses, cold, and flu and should definitely be prescribed in those cases (Llor, 2014). This is alarming because none of those illnesses will be improved by antibiotics. Antibiotics are effective only against bacterial infections, not against viruses like the ones that can cause ear infections, respiratory infections, flu, and the common cold.

Patient characteristics that coincide with excessive and unnecessary antibiotic prescribing include misperceptions about antibiotic effectiveness for viral illnesses, desire for a tangible product from the clinical encounter, age, ethnic and racial identification, and insurance status (Ackerman, 2012). Older patients, patients from underprivileged areas, and minority patients were the groups that received unnecessary antibiotics the

most. Ackerman suggests that the listed characteristics incline these patients to being those with whom it is more difficult to converse with and explain unpleasant or complicated information. These boundaries do make for a sometimes difficult provider to patient interaction, but in order to rectify the antibiotic crisis these obstacles will have to be surmounted. Social characteristics of the doctor-patient relationship as listed above must definitely be considered when looking at the issue of antibiotic over-usage. However, the ongoing cultural shift in the expected role of the patient—from passive receiver of medical expertise to active medical "consumer" must also be heavily considered (Ackerman, 2012). People expect to be sold something and, when they are turned away without medication, they feel cheated or short changed in some way. The consumer mindset of American culture is a definite contributing factor to the antibiotic crisis.

Role of Uncertainty

The uncertainty involved in diagnostic testing also contributes to overprescribing of antibiotics, particularly in the primary care setting. A Dutch study done in 2005 showed that the use of antibiotics was very strongly linked to physicians wanting to avoid uncertainty in diagnosing patients rather than actual clinical indications of a bacterial illness (Llor, 2014). Physicians want to eliminate the possibility of withholding antibiotic treatment from a patient only to have them suddenly develop a serious bacterial infection and become severely ill or even die. The legal repercussions and moral questions weigh heavily on the backs of doctors facing these choices. The problem is that the likelihood of misdiagnosing a life threatening bacterial infection as a self-limiting viral illness is incredibly small. By providing a "blanket coverage" antibiotic prescription just to ease

the patient's worries or prevent repercussions for the physician, the crisis of antibiotic resistance is being further propagated. It is not beneficial to the patient or provider to practice antibiotic prescription for "just in case" scenarios.

Role of Agriculture

The overprescribing of antibiotics within the hospital setting and the primary care setting is a growing problem that is heavily contributing to the antibiotic crisis. The utilization of antibiotics in other areas of society, such as agriculture, farming, and aquaculture, are also on the rise (Llor, 2014). Recent data show a direct correlation between the use of antimicrobials in these areas and the rising resistance of microbes to the antibiotics used (Blaser, 2014). Farms are able to acquire antibiotics with little to no regulation. Animals are often fed antibiotics as part of their normal nutritive regimen rather than as a medical treatment when they fall ill (McKenna, 2012). This complete lack of regulation as far as antibiotics used in agriculture, farming, aquaculture, and the care of animals is a definite contributing factor to the rising antibiotic crisis.

Role of Medical Practice in Foreign Countries

Further exacerbating the crisis is the looseness with which antibiotics are used and sold in much of the rest of the world. The United States has begun to put many programs and laws in place to prevent the excessive use of antimicrobials, but a great deal of the world continues to lag behind. Self-medication with antibiotics is extremely common in many countries. Particularly in developing countries, antibiotics are sold either illegally, without a prescription, or legally in drugstores without a prescription (Llor, 2014). This situation looks very similar to what can be looked back upon in the early days of

antibiotic usage in America. These practices are especially common in countries in Asia, Africa, South and Central America, and some Southern European countries such as Italy, Spain, Greece, and Malta (Levy, 2002). It is absolutely critical to recognize that this is by no means just an American crisis. Antibiotics are used world-wide on a magnificent scale and microbes everywhere are developing resistance to these antibiotics. The entire world is being affected and will continue to be affected. World-wide misuse of antibiotics is a definite barrier to developing a cohesive strategy to reversing what damage has been done and preventing further damage; it will be incredibly difficult to convince all the countries of the world and their governing bodies to work together.

Antibiotic Resistance

Bacteria are becoming alarmingly antibiotic resistant. One bacteria in particular, *methicillin-resistant Staphylococcus aureus,* has gained quite a bit of infamy for being nearly impossible to treat (Bonomo, 2007). Neu states that in 1941, virtually all *Staphylococcus aureus* strains worldwide were susceptible to and treatable with penicillin. By 1944, *S. aureus* was capable of destroying penicillin by producing penicillinase (aka as beta-lactamase). About fifty percent of *S. aureus* strains were resistant by the end of the 1940s (Shallcross, 2016). Presently, over ninety-five percent of *S. aureus* is resistant to not only penicillin, but also ampicillin and the antipseudomonal penicillins (Neu,1992). Hospitals are breeding grounds for bacterial infections, not because of bad sanitation or filthy conditions, but because they provide an ideal environment for the development of multi-drug resistant bacteria by promoting the reproduction and growth of the particular strains of bacteria that carry the gene for drug resistance. *Clostridium difficile* is another perfect example of this phenomenon. When

antibiotics are used unnecessarily or indiscriminately, the normal bacteria that live in the gut can be disrupted and killed, allowing for drug- resistant bacteria to move in. *C. difficile* is the most prominent of these bacteria, causing opportunistic infections in patients who have been treated with antibiotics and, on occasion, leading to a persistent and debilitating disease that is often incurable (Lashley, 2002).

Antimicrobial treatment places selective pressure on bacteria. This pressure favors the emergence of strains of the microbe that will be resistant to the antibiotics in the environment and therefore able to survive and reproduce (Shallcross, 2016). Bacteria are able to resist antibiotics as a result of their genetic and mutational abilities. This can include chromosomal mutation, inductive expression of a previously latent chromosomal gene, exchange of genetic material through transformation, transduction by bacteriophage or conjugation by plasmids which are extrachromosomal DNA (Neu, 1992). Plasmids are a current target of a large amount of antibiotic research. Bacteria may also possess transposons. Transposons have been nicknamed “jumping genes” due to their ability to enter transmissible plasmids or chromosome and thereby spread antibiotic resistance not only to other bacteria of the same species but to different species of bacteria (Bonomo, 2007). Gram positive species have demonstrated the ability to transfer resistance to Gram negative species, although the reverse is uncommon (Neu, 1992). This collaboration and cooperation of different species of bacteria is a wonderful testament and example to the intelligence and adaptation abilities of microbial life, given to them by their Creator.

Bacteria evade antibiotics in three major ways. They can inactivate the antibiotic by destroying it or modifying it in a way that makes it unable to negatively affect the microbe. Secondly, they can evade the antibiotic or prevent its access to the microbial

body. Lastly, they can alter the antibiotic target site on their membrane surface, which will prevent the antibiotic from binding. Therefore, it will have decreased or no effect on the microbe (Neu, 1992).

Potential Solutions

Several methods for the prevention of further drug resistance development have been suggested by scientists, physicians, and other professionals. These include educating the public about the proper use of antibiotics and the consequences of misusing them, holding physicians and health care professionals to a much higher standard when it comes to diagnosing and then treating patients with bacterial illness, putting stricter regulations in place for when antibiotics can and should be prescribed, and increasing the search for new antibiotics. Multifaceted interventions that attack the problem from several sides have shown to be the most effective in fighting back against antibiotic resistance. The interventions that have shown the best results in countries worldwide include: the enforcement of policies prohibiting the sale and purchase of antibiotics without a valid prescription from a qualified dispensing pharmacy, the use of stewardship programs explaining the importance of the proper use of antibiotics to the public, the enforcement of laboratory testing before prescribing antibiotics, teaching physicians how to better manage patient interactions, and putting incentives in place for physicians who adhere to these guidelines and regulations (Jung, 2015). These steps, among others, are probably necessary to prevent society from being thrust back into the time before antibiotics.

Public Antibiotic Education

The public is seriously misinformed about when an antibiotic is necessary and when it is not. There is a clear need for education in this area (McKenna, 2016). Including material about antibiotics and their safe usage into public school curriculum plans could go a long way in informing the general public about the realities of antibiotic use. Informative pamphlets could be given out in government buildings such as the Social Security Office and the DMV when people come in for other purposes. Television could be particularly useful in this aspect. Documentaries and news stories could go a long way towards educating the public. Social media could also potentially be used as a platform in spreading the news about antibiotic resistance. Public intervention could include the publication of guidelines, freely offered educational sessions covering what illnesses antibiotics will and will not work for, the publication of local interviews with pharmacists, messages on radio, television, and other mass media platforms, etc. (Llor, 2014). These public campaigns will certainly have a positive effect on reducing the antibiotic crisis, but educating the public will by no means solve the antibiotic crisis. It is simply a first step in the right direction.

Physician Programs and Interventions

Since bacterial infection is genuinely hard to distinguish from viral infection at times, physicians and providers must be encouraged and even required to run diagnostic tests before prescribing antibiotics to a patient (McKenna, 2014). Not only will this remove the guesswork and put the physician's mind and conscience at ease, but also it will make the subsequent, often uncomfortable explanation to a patient about the reason they are not being prescribed an antibiotic "just in case" a thing of the past. The patient

could be much less likely to put pressure on a provider to prescribe antimicrobials in situations in which they are not indicated or warranted. Diagnostic tests are, generally, quite simple. They usually entail taking a swab, blood sample, or urine sample and sending it to the laboratory. Diagnostic testing may take a little longer and seem like an inconvenience to the patient, but the time lost from their day will pale in comparison to the impending antibiotic crisis if these measures are not taken. This is not meant to trivialize a patient's concerns, but to help them understand how antibiotics can and should be properly used for the betterment of their health and the health of society as a whole. Obviously, there may be cases that are too severe to call for diagnostic testing before giving a patient antibiotics. This is a situational concern that allowances would need to be made for. Perhaps hospitals could have allowances for the prescription of emergency antibiotic medication.

Including antibiotic training as part of a physician's medical education could prove immensely valuable, particularly as it pertains to conversations with patients. It is important that physician knows how to discuss the correct use of antibiotics and knows how to adequately explain to a patient with no medical background or understanding that antibiotics will not reduce the duration of viral or self-limiting diseases and that they may actually be contributing to the antibiotic crisis. The information given verbally by the provider could be backed up by informational leaflets or pamphlets that the patient can take home (Ackerman, 2012). It is also important that doctors can set realistic expectations for patients about the duration and severity of the illnesses they are experiencing. Four days is a common running time frame for ear infections, about a week for an acute sore throat caused by a virus, a week and a half for the common cold, two

and a half weeks for a sinus infection, and up to three weeks for a severe cough or bronchitis (Llor, 2014). This is of particular importance because studies have shown that many patients believe that if they suffer symptoms for more than three days, antibiotics are not only warranted but absolutely necessary (Battin, 2009).

Regulations

The antibiotics currently in use must be conserved and protected while the search continues for other antibiotics (McKenna, 2012). It may be necessary to only allow IV administration of antibiotics in life-threatening cases while a patient is in the hospital. Oral antibiotics could be temporarily done away with to ensure that the medication is being taken only when necessary and in the correct dosages, for an adequate amount of time. This would remove the necessity of educating the public and trusting the common man to safely and responsibly use antibiotics. The ultimate goal of putting regulations into place regarding the acceptable use of antibiotics is not simply to reduce the number of antibiotics being prescribed and utilized. It is primarily to encourage the rational use of antibiotics and to ensure that they are only being prescribed to patients who need the treatment and will definitely benefit from it (Llor, 2016). The CDC has actually already put a program into the works that would do just what is being proposed here. It is a quite aggressive plan aimed at reducing the unnecessary and frivolous use of antimicrobials so that antibiotics remain a viable tool for future generations to come (Arason, 2016). In fiscal year 2016, Congress appropriated nearly $160 million for the CDC to allot to different agencies and programs in the fight against antimicrobial resistance. With these investments, CDC implemented the Antibiotic Resistance Solutions Initiative, which is improving national infrastructure to detect, respond, and contain resistant infections

across healthcare settings and communities. This plan does have its flaws. It is aimed primarily at hospital use of antibiotics, not towards general practitioners of family practitioners. Also, the CDC's proposed plan does not address the use of antibiotics in agriculture and livestock. The CDC includes several categories of goals in the fight against antibiotic resistance. They hope to set national goals to improve antibiotic use, particularly to cut inappropriate prescribing practices by fifty percent in hospitals and twenty percent in the general practitioner and specialists' offices. They plan to encourage effective public information and antibiotic stewardship programs, focusing their efforts on doctors' offices, hospitals, and nursing homes. The CDC has provided funding to researchers who are studying antimicrobial resistance and those who are searching for new antimicrobial substances that could potentially be medicalized and used in the treatment of patients. Interestingly, they also have begun a program in support of the early recognition of sepsis (Mayer, 2008). All of these initiatives sound very noble and promising. However, the CDC has yet to set forth a practical approach to fighting antimicrobial resistance. All of their planning thus far has been focused toward future initiatives, not the here and now. Unfortunately, the antibiotic crisis is happening today, not in the distant future.

Pharmaceutical companies must be removed from their place of authority in antibiotic production. They should be prevented from offering prescribing incentives to medical providers, potentially through legal action. This is probably one of the toughest issues to be overcome. It may be impossible to remove pharmaceutical companies from their place of authority and power without putting the government in control of pharmaceutical production. Government control would undoubtedly be a worse

alternative. For the time being, the role of unsavory "big pharma" must be recognized and possibly countered by public pressure and incentives.

Antibiotics for use in animals should be administered only by a licensed veterinarian directly or through writing a prescription that a pharmacy can fill (McKenna 29). Antibiotics should by no means be sprayed onto crops or included in the food of livestock as a preventative measure. The link between animal health and human health must be clearly recognized and integrated into the approach taken by health professionals, regulatory agencies, and the enforcing authorities (Shallcross, 2014).

Search for New Antibiotics

The search for new antibiotics is well underway, though it is moving at an alarmingly slow rate. It is much more difficult for researchers to find financial support from pharmaceutical companies to search for and develop these new drugs. The time delay between the discovery of a potential new antimicrobial substance and the approval to commercially produce it is on the magnitude of decades (McKenna, 2014). This has led many researchers to abandon the search for new antibiotics entirely, as there is not enough interest or funding.

Possible Consequences

What is of most concern is that common bacterial infections such as strep throat may once again become untreatable due to bacterial resistance (McKenna, 2014). The World Health Organization has outlined what a possible future could look like if antibiotic resistance grows any higher. They have named it the "post-antibiotic world". This world looks a lot less like Pasteur's hope of the future destruction of disease and

much more like the pre-penicillin era when infectious disease dominated. The WHO warns that antibiotic resistance may soon result in simple infections becoming unmanageable and potentially even fatal (Mainou, 2000). McKenna (2014) agrees, stating that "What is of most concern in the antibiotic crisis we are currently facing is that simple infections that we scoff at such as a sore throat or a UTI may become untreatable" (p. 15).

Antibiotics and Microbes as Part of God's Good Creation

Microbes as Part of God's Creation

Microbes are unbeatable. They were created by God as a beautiful and unavoidable part of his perfect creation. They were affected negatively by the Fall and introduction of sin into the world. The symbiotic and perfect relationship of microbes to man was broken, and microbes became parasitic and harmful to the human body. Nevertheless, they are indivisible from humanity and from the rest of creation. By all consideration, humans are sharing the microbial world, not the other way around, as humanity is inclined to believe. Microbes are not encroaching on man's world; they are an established part of God's creation with which humanity is meant to live in relationship. Bacteria are infinitely more plentiful and numerous than humans or any other living creature. Estimates suggest that microbes make up ninety percent or perhaps more of all life on Earth (Schmidt, 2009). This thought may seem absolutely terrifying given the information known about pathogens and the number of people killed by infectious disease each year. Fortunately, the vast majority of bacteria are either beneficial to the human race and the world or, at the very least, not harmful to the rest of creation. Microbes are responsible for reforestation, enrichment of soil, plant growth, and

all animal life. The physical world is driven by bacterial life that remains unseen to us (Schmidt, 2009). Schmidt goes so far as to suggest that in order to adequately react and respond to the antibiotic crisis, we must "accept the humbling notion that we are living in the microbe's world. If we accept this we are well on our way to thriving in that world. In order to do so, however, we must surrender another sacred belief – our belief about what it means to be humans" (p. 19). This stance goes a bit too far in the lens of a Christian worldview based on Scripture as the inspired word of God. God did create humanity separately and special. Human beings are uniquely created in the image of God himself. As such, humanity is in a position of priority in the natural hierarchy. God has given mankind dominion over the rest of creation along with a mandate to rule over, care for, and shepherd creation. Microbes may be more plentiful than humanity, but humanity by no means needs to be subservient to bacterial life. Rather, microbes must be viewed as part of God's good creation that are meant to be held under man's careful and considerate rule. A healthy respect for microbial life, as well as an understanding of their role in God's creation, is absolutely vital to beginning to solve the antibiotic crisis. McKenna speaks about the role of microbes in nature very beautifully. He says, "We must accept that even pathogenic, disease causing bacteria have a positive and important part to play in nature. We do not have to understand what this role is; we need only respect it. And respect is the key to solving the problem of bacterial resistance" (p. 33).

Antibiotics as Part of God's Creation

It is undeniable that antibiotics have done an incredible amount of good for society and humanity. The widespread use of antibiotics in the decades following the introduction of penicillin into society has led to extended average life expectancy by two

decades. The leading causes of death for Americans are now non-communicable diseases such as heart disease, diabetes, and cancer as opposed to infectious disease like pneumonia, tuberculosis, and others. Antibiotics have fostered an environment allowing for major advances in cancer treatment, organ transplantation, and surgery (Shallcross, 2016). Modern medicine has undoubtedly been bettered by the use of antibiotics.

Antibiotic over-usage is very clearly leading to drug resistance in bacteria. If this trend continues, antibiotics will no longer be effective and many bacterial infections will once again be untreatable. Surgery could once again result in more deaths from post-surgical infection than in patients restored to health. Child birth will be an extremely treacherous and dangerous process. A small scrape on the knee after falling off a bicycle could potentially lead to systemic infection and death of a precious child. A world like this is not hard to imagine because this was reality only 60 years ago. The past will soon become the future if measures are not taken to change the current path society is traveling. The dark future that Dr. Fleming foresaw and wisely warned against, could all too soon be realized.

Fortunately, all is not lost. Many experts and professionals have set forth possible solutions to the antibiotic crisis. These include patient interventions, regulations on physicians, pharmacies, and pharmaceutical companies, social media initiatives, and a holistic approach to viewing medicine. It is immensely comforting to realize that God created bacteria as part of his good and perfect creation. They are a necessary part of not only the Earth but the human body itself. Humanity and bacteria were created to coexist, with humanity exerting its God-given dominion.

God is a good God and a perfect, intelligent creator. The antimicrobial crisis is scary and does require human intervention. It also requires prayer and a desire for God to right his creation. Bacteria will one day be restored to their pre-Fall conditions of peaceful and perfect coexistence with humanity. Until that time, it must be the goal of the medical and scientific community, as well as the world as a whole, to prevent the further development of antibiotic resistance. The apostle Paul shared a few words of wisdom that can be easily and beautifully applied to the present antibiotic crisis. Romans 8:18-24 states, "I consider that our present sufferings are not worth comparing with the glory that will be revealed in us. For the creation waits in eager expectation for the children of God to be revealed. For the creation was subjected to frustration, not by its own choice, but by the will of the one who subjected it, in hope that the creation itself will be liberated from its bondage to decay and brought into the freedom and glory of the children of God. We know that the whole creation has been groaning as in the pains of childbirth right up to the present time. Not only so, but we ourselves, who have the first fruits of the Spirit, groan inwardly as we wait eagerly for our adoption to sonship, the redemption of our bodies. For in this hope we were saved." The Bible promises that not only will humanity be restored and redeemed, but all of God's creation will be once again made new and perfect. This hope is the true solution to the modern day antibiotic crisis.

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