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Governing the Infections Bacteria Commons: Preventing Antibiotic Resistance

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Antibiotic Resistance: A 21st Century Challenge

In 1862, during the battle of Fair Oaks, George Fisk took a bullet to the shoulder. As he lay in Washington's Judiciary Square Hospital, his wound became infected and was soon a swollen, puss- and blood-filled mass. The doctor chose not to amputate, and several days later, Fisk died from infection.[1] In 2006, Sgt. Nathan Reed was escorting a news team through Baghdad when his leg was seriously injured by a roadside bomb. While in the hospital, Reed contracted an antibiotic resistant infection. The bacterium causing the infection has made the short list for dangerous microbes because of the toll it has taken on soldiers in the Middle East. Because the risk of trying to fight this particular strain of bacteria is so high, Reed's doctors advised him to choose amputation, which he did rather than risk his life trying to save his limb.[2]

Though the treatment they received was separated by more than one hundred and forty years of medical science, both Fisk and Reed faced a life or death decision because of the bacterial infection they contracted. Yet there was a time, between the Civil War and now, when the majority of infections were easily treated. For a time, Penicillin and other antibiotics made life threatening bacterial infections a thing of the past.[3] Unfortunately, antimicrobials have been misused and overused and this has lead to the growth and spread of bacteria that are resistant to antimicrobials. These bacteria do not only affect wounded soldiers. According to the FDA, "Disease-causing microbes that have become resistant to drug therapy are an increasing public health problem. Tuberculosis, gonorrhea, malaria, and childhood ear infections are just a few of the diseases that have become hard to treat with antibiotic drugs." [4]

Natural selection is easily observed in bacteria because of their short lifespan and phenomenal reproductive rate. Antibiotics are extremely useful when combating pathogenic bacteria. However, after an antibiotic is used repeatedly, bacteria begin to develop a resistance.

This is because the few bacteria with mutations that make them immune to the antibiotic are selected for, while those without those mutations are selected against. Therefore, using antibiotics increases the likelihood that resistant strains of pathogenic bacteria will survive while their counterparts die. As Dr. Lewis said, “In many ways, antibiotic resistance has developed along basic Darwinian evolutionary principles. As more and more antibiotics are used, organisms that possess genes that make them resistant to antibiotics are more likely to thrive and, therefore, are more likely to pass on those genes. Over many years, this pattern has had a significant effect on the evolution of infection-causing organisms." [5]

There are several factors contributing to the increase in antibiotic resistance among bacteria, the most prominent of which is doctors’ over-prescription of antibiotics.[6] [7] Individuals are often saved by using antibiotics. However, every time an individual uses an antibiotic, they are increasing the chances of the gene pool of infectious bacteria becoming more resistant to that antibiotic. Because antibiotics are cheap, and often extremely effective, individuals have incentive to use them on a regular basis.[8] When people use antibiotics regularly for a long period of time, bacteria become so resistant that the antibiotics become close to worthless. This type of dilemma is known as a tragedy of the commons. The term *tragedy of the common*s was coined by Garret Hardin to describe a situation in which rational self-interest forces each individual actor to exploit a common resource. The result is that everyone’s freedom to act in a self-interested way forces everyone to race to exploit the resource, eventually bringing the destruction of the resource and suffering for all.[9] If people only used antibiotics in cases of serious need, mankind would reap the benefits. As it were, the welfare of the human race is of little significance to individuals who know using antibiotics will give them relief from their immediate suffering. The incentive is even smaller when an individual knows that others are also overusing the same antibiotic, and it will eventually become ineffective.

The gene pool of infectious bacteria should be considered a common-pool resource. Over two-hundred and fifty organizations with members from fifty different countries have signed a treaty which recognizes the global gene pool as a common pool resource.[10] The gene pool of infectious bacteria has the characteristics of a common pool resource which, as defined by Ostrom and Ostrom, are resources that are hard to exclude people from and when used, become more difficult for another to use.[11] The gene pool of infectious bacteria has low excludability because it is hard to keep people from using antibiotics. Antibiotics and the infectious bacteria gene pool posses the quality of subtractability because one person's use of an antibiotic increases the chance that later users will find antibiotics less effective. While the supply of antibiotics is not noticeably limited, the number of times antibiotics can be used effectively is.

When examining a common pool resource, it is critical to have a proper understanding of the elements that affect that resource.[12] This paper will examine several of the elements identified in the Institution Design and Analysis (IAD) framework, as discussed by Ostrom. Ostrom and colleagues say the IAD framework should be used to examine common-pool resources. IAD examines each aspect of an action situation by categorizing the different elements and then examining how they interact. This paper will take an *institutional* approach by focusing on the rules humans can develop to address the threat of spreading antibiotic resistance. The question this paper seeks to answer is "*What is the proper institutional response to the overuse of antibiotics and the threat of spreading antibiotic resistance*?"

This paper will treat the lack of antibiotic resistance among the gene pool of infectious bacteria as a common pool resource and examine the institutions designed to protect this resource through the perspectives provided by common pool resource theory. This paper will examine the United States and the Netherlands, two cases which support the theory surrounding the governance of common pool resources. Finally, after using governance of the common's theory and the lessons learned from different national level approaches to combating antibiotic resistance, this paper will make some recommendations for institutional change in countries like the U.S., who are struggling to keep antibiotic resistance under control.

A Short History of Antimicrobial Resistance

In the 1940's, Penicillin changed the world by turning life-threatening infections into easily treated inconveniences.[13] [14] During World War II, the Allies had an unprecedented low amount of deaths due to disease because of this new technology.[15] The United States and Britain were so impressed with the results of Penicillin that by D-Day the two countries were producing a billion units per month. [16] Penicillin's unprecedented effectiveness combined with the ease with which it can be produced has lead to its wide spread use.[17] Unfortunately, bacteria have been able to adapt. By 1942, pathogenic strains of bacteria began showing signs of resistance to penicillin and now penicillin is completely ineffective against many of the newer, mutated strains of bacteria.[18] Penicillin is still the most widely used antibiotic, [19] however, its possible uses are continually narrowing because more and more strains of penicillin resistant bacteria are developing. [20] By 1961, Patricia Jevons reported that only two percent of all remaining strains of S. aureus, a common pathogenic bacterium in England, could be treated with Penicillin.[21] Because of the extensive use of Penicillin in England, ninety-eight percent of staphylococcus aureas (S. aureas) strains were already completely immune to what was once a potent antibiotic.[22] The response of the medical and scientific communities was to develop new antibiotics, such as methicillin, one of the first semi-synthetic antibiotics that could kill penicillin resistant bacteria.[23] [24] However, S. aureas has now developed several hardy, methicillin-resistant strains. In 2004, it was reported that in the U.S., sixty-four percent of staph bacteria were resistant to methicillin.[25] These methicillin resistant S. aureas (MRSA) often posses immunity to multiple antimicrobials.[26] Patients who contract MRSA are four times more likely to die than other patients.[27] In order to effectively treat these bacteria, more potent antibiotics have been developed.[28] Extremely potent antibiotics are able to kill most resistant bacteria, but they often cause harmful side effects. Vancomycin is a newer antibiotic that is used to treat infections resistant to methicillin,[29] however, it is so potent that doctors prefer to use it only as a final resort, when all else fails.[30] Now there are new strains of infectious bacteria that show complete resistance to Vancomycin.[31] What is worse is that some of these bacteria seem to be resistant to everything and are thus termed “superbugs."[32]

The cycle repeats itself. An antibiotic is developed and then the bacteria mutate and form a resistance so that another antibiotics must be developed. John Powers, a lead medical officer and researcher for the National Institute of Allergy and Infectious Diseases, describes each antibiotic as a “tank of gas” that has a limited number of uses, and claims: “When it runs out, it runs out."[33] Unfortunately, it is becoming very hard and very costly to develop new antibiotics that are effective against the increasingly resistant strains of bacteria.[34] Therefore, the supply of new antibiotics is limited.[35] In the past, physicians were able to defend the careless overuse of antibiotics by pointing to the continuous stream of new, effective antibiotics.[36] This cannot continue because the supply of new, effective antibiotics, and the rate at which they are being produced, is quickly diminishing.[37] If the number of resistant bacteria continues to grow, we may find ourselves fighting infections from a position similar to the days before penicillin.[38]

The development of antibiotic resistant bacteria can be avoided, or at least, substantially slowed.[39] These bacteria are most likely to develop when antibiotics are used liberally and irresponsibly.[40] For example, many of these bacteria are developing as a result of feeding antibiotics to animals.[41] Farmers find antibiotics a cheap and effective way to keep their animals free of infection.[42] The problem is that after extensive use, strains of bacteria that are resistant to the antibiotics begin to emerge.[43] These bacteria enter the soil, air, or water, and eventually come in contact with humans. Some scientists claim that "Keeping antibiotics out of animal feed in the first place is the best way to limit the development of antibiotic resistance and keep antibiotics working in humans." [44]

Another way antibiotics are irresponsibly consumed is when people take them as preventatives or use them without proper diagnosis (Lowy 2003).[45] Many people take antibiotics when they have a common cold in case their symptoms are the result of an infection.[46] The result is that they are often doing nothing to combat their cold and they are increasing the likelihood of antibiotic resistant bacteria. The same thing happens when doctors misdiagnose a symptom as being the result of an antibiotic treatable bacterium when the patient is really suffering from something else.[47] Finally, antibiotic resistant bacteria occur quite often in cases where a patient suffering from a bacterial infection does not take the full prescription of antibiotics.[48] The result is a long touch and go battle with the bacteria which gives the bacteria time to develop a resistance to the antibiotic being taken.[49] There is always hope that new, stronger antibiotics will be developed or new methods for combating infection will be discovered. However, as these technologies are pursued, more must also be done to stop the continual spread of antibiotic resistance.

Common Pool Resource Theory

Charlotte Hess has studied commons for over eighteen years.[50] In her paper, "Mapping the New Commons," she identifies six "triggers" which lead people to identify a resource as a commons. One of these identifying triggers is the occurrence of a tragedy of the commons.[51] Hess says that there is a need to quickly identify threatened commons before they are depleted or destroyed. [52] Hess quotes Levine, who said, "People must exhibit mutual trust, habits and skills of collaboration, and public spirit in order to sustain such a common pool resource against the tendency of individuals to abuse it." [53]

Over the last twenty-five years, there has been tremendous growth in the knowledge and theory surrounding common-pool resources.[54] There is still much to be discovered in this new field, however, the existing theory already has the ability to lend considerable wisdom and insight to those attempting to preserve a common-pool resource.[55]Social interactions surrounding common-pool resources do not always degenerate into a tragedy of the commons.[56] Tragedy of the commons scenarios most often occur when the users of a common-pool resource have difficulty communicating and interacting in such a way as to develop trust.[57]

Peter Kollock, a professor of sociology at U.C., defines "social dilemma" as a scenario in which "individually reasonable behavior leads to a situation in which everyone is worse off."[58] Kollock describes the social dilemma in a tragedy of the commons as a "social trap" in which each individual can either choose immediate benefit that incurs future hardship on all, or forego immediate benefit so as not to cause hardship on everyone. Kollock says that individuals often have incentive to choose the immediate benefit, and when enough individuals choose this, the common pool resource is depleted.[59]

Kollock provides an example scenario in which there is a forest that people are able to harvest trees from. Every time a person takes trees from this forest, there are fewer trees for everyone else to harvest. However, the benefit to the individual of having lumber is much greater than the cost of not being able to harvest these trees again. Harvesting trees makes even more sense for the individual who considers that if he or she does not harvest them, someone else will. Unfortunately, when all the individuals follow this logical path and harvest the trees, the forest is soon depleted.[60] What these individuals need to do is come together and create an *institution* (i.e. rules that restrict individuals from overharvesting and thus prevent the resource from being depleted). Kollock notes that one of the most important factors for those creating the rules to consider is the rate at which the resource replenishes itself.[61] This knowledge is essential when trying to determine the maximum sustainable rate at which the community can use the resource.

Finding the elements which make up a successful common-pool resource governing institution has been the aim of a considerable portion of the research surrounding common-pool resources. Kollock's research lead him to conclude that frequent communication and easy access to information were both critical components of successful institutions.[62] Eleanor Ostrom, a leader in the study of common-pool resources, who was awarded the 2009 Nobel Prize in Economic Science for her work, agrees with Kollock. When she examined institutions that were developed by groundwater consumers in the L.A. basin to preserve sustainable levels of groundwater, she concluded that it was of paramount importance that those working within the institution know each other's actions and be able to ascertain the general level of compliance with the rules. Ostrom found that when everyone's use of groundwater was metered, published, and distributed, the threatened sanctions for misbehavior never needed to be enacted . If one person overused water, everyone learned of it, and therefore, individuals were very quick to correct their misbehavior.[63] When individuals have enough information to determine that others are obeying the rules outlined by the institution, the institution gains credibility, and voluntary compliance is more likely.[64]

In “Governing the Commons: The evolution of institutions for collective action,” Elinor Ostrom examines four common-pool resources which have been successfully governed for an extended period of time without external assistance. These four common-pool resources are land in the Swiss mountains, the forests in Japan, the water in arid Spain, and irrigation systems in the Philippines. In the Swiss mountains, communities used a system which involved both private land for agriculture and communal land for grazing and wood gathering. In Japan, forests and land were extremely scarce and thus crops were harvested and shared by the community. In Spain, water was extremely scarce and the supply was very unpredictable. However, communities found ways of agreeing upon how to allocate the water and closely self-regulate that usage. In the Philippines, a set of rules was devised for determining the amount each should contribute to the maintenance of the irrigation systems. This system was carefully created in a way which was fair so that those who put effort into the system were able to reap a proportional reward. [65]

Ostrom identifies common characteristics among the successfully managed commons she discusses. They had clearly defined boundaries. They had rules which were specifically tailored for that resource and took into account its abundance, reliability, frequency, sustainability, and other characteristics. The institution could be changed by the those it regulated. The use of the resource was carefully monitored, and the systems for monitoring were part of the institution of governance. The institution was enforced by sanctions that took context into consideration, became greater after repeated violations, and were proportional to the grievances. The institution had a system for resolving conflict. The community's institution was recognized as legitimate by outsiders. Finally, in the common-pool resources that were integrated into a larger economical system, the different aspects of the governing institution were organized into "nested enterprises."[66] By identifying the characteristics common to successful institutions, Ostrom gives guidance to those hoping to create new, successful, and long-lasting institutions for the preservation of endangered common-pool resources.

Stern et, al. offer complimentary advice in their work "Knowledge and Questions after 15 years of research."[67] They claim that when crafting an institution to protect a common-pool resource, it is important to have an understanding of the actors involved and the incentives they face. [68] It is best when those who use the resource are also those who are monitoring resource use and enforcing rules. Stern et. al. found that the success of an institution is often connected to participants ability to create the rules and sanction inappropriate actions. Stern et. al, also concluded, in agreement with Ostrom and Kollock, that systems of monitoring are essential to the preservation of a common pool resource.[69]

Case Studies

Stern et, al. advocate case studies as a method for mapping and examining new commons.[70] They say that, "In such frontier research areas, in-depth observation is needed to uncover phenomena or variables that would be missed if researchers only looked at variables known to be important."[71] They also note that case studies can be used to test the application of theories or to develop new theories.

The purpose of this paper is to formulate and then support recommendations for institutional change in countries which are struggling with a tragedy of the commons in the realm of antibiotic resistance. By examining different national level interactions with antibiotic resistant disease, one can search for policies which have worked as well as policies which have failed. One can also use these case studies to test common-pool resource theory and its application to antibiotic resistance. The nation-state is a complex collection of people, culture, geographical features, and institutions. When studying two or more nations, it is hard to draw direct comparisons. It can be even more challenging to determine to what extent each factor considered caused the observed results. Therefore, this paper will use the case study method, which allows for a detailed description of different cases, a discussion of the results achieved in each case, and a cross-case comparison.

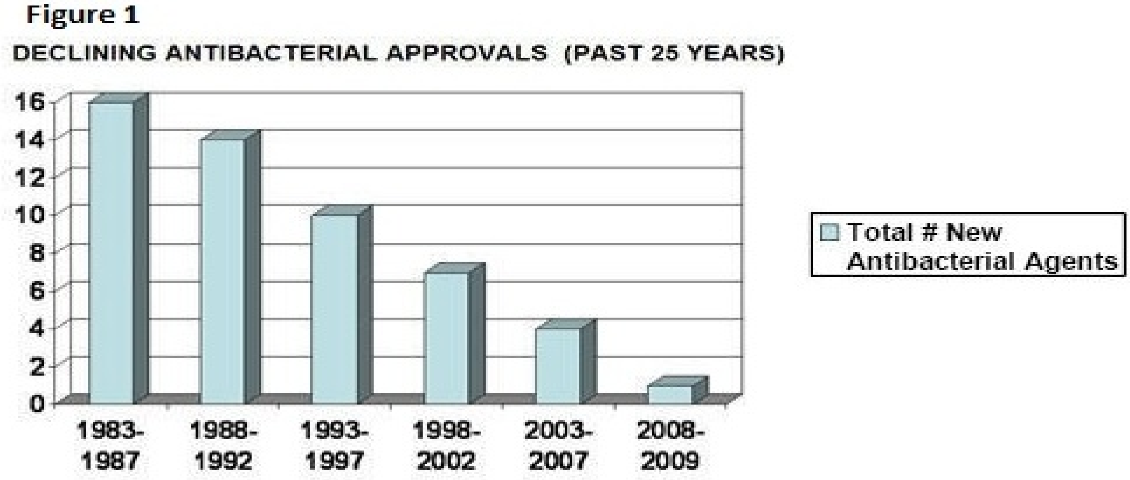
The following case studies will examine antimicrobial resistance at the nation-state level, because this is currently the optimal level for the implementation of institutions designed to combat antimicrobial resistance. Antimicrobial resistance does not respect political boundaries, and therefore, the failure of one hospital, city, or state can negatively affect its neighbors. Though one state may do an excellent job rationing antibiotics and eliminating resistance, its hard work can be undermined by an infection which spreads from another state. [72] The same can happen across national borders and so ideally, a global level institution could be used to enforce the rational use of antibiotics. Unfortunately, international institutions lack sanctioning power, and there is currently no international level institution that has the ability to provide proper incentives and sanctions. Therefore, collective action crafted to lessen the impact which antimicrobial resistance has upon humans should be directed from the national level.

The following case studies will examine the United States and the Netherlands. Two developed, western nations that have adopted different approaches to controlling the spread of antibiotic resistance.

United States

The United States is a nation that privileges freedom and individual choice. The people of the United States have historically favored individualism over collectivism, unlike the societies of Japan, China, and Europe.[73] Individualism places importance upon the individual rather than the collective. Individualism stresses virtues like independence and self sufficiency. The political doctrine of individualism holds that "The interests of the individual are or ought to be ethically paramount." [74] A free market is a natural component of an individualistic society.[75] The market for antibiotics in the U.S. is a relatively free market, though patients must have a prescription in order to purchase them.

In most cases, the United States free market approach has provided abundant incentive for pharmaceutical companies to develop new drugs. In 2002, the companies based in the United States spent 15 billion dollars on research and development for medicine.[76] Though the investment is huge, the financial return has been even larger and the social benefit of the investment has been an increase in new, innovative and efficient treatments. [77] Twenty percent of what American's spend on new medicine is funneled back into medical research and this is funding an ever-increasing amount of biomedical innovation. [78] In 2002, eighty-nine new medicines were introduced into the U.S. market, but for the first time in several years, not a single new antibiotic was approved. In fact, as demonstrated by figure 1, the number of new antibiotics approved by the FDA has continued to decline.[79]



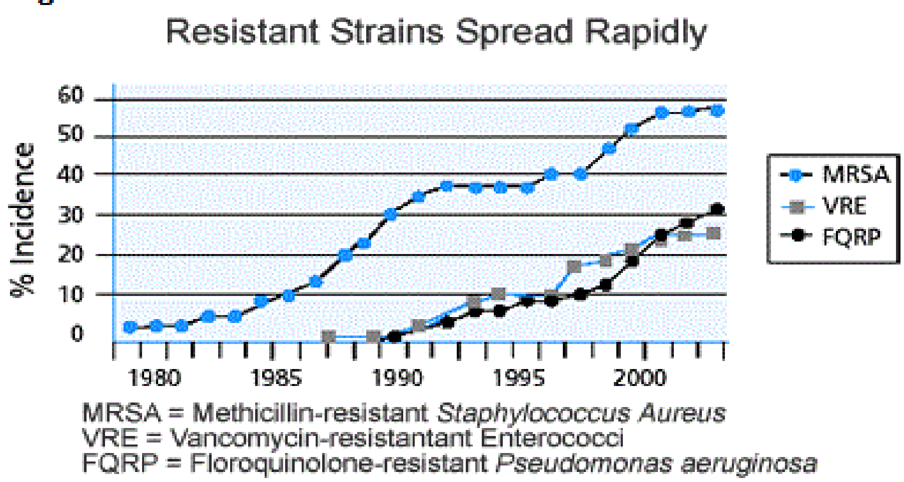
Infectious Diseases Society of America (2010). Retrieved from <http://www.idsociety.org/badbugsnodrugs.html>

Figure 1 shows the number of new antibacterial agents approved by the FDA per five year period. The figure shows that from 1983 to 1987, the FDA approved sixteen new antibacterials. The figure also shows that from 2003 to 2007, the FDA only approved four new antibacterials. Over that twenty-five year period, discovery and approval of new antibacterials decreased seventy-five percent. In the last two years, 2008 and 2009, only one new antibacterial has been approved.

The free market is not providing enough incentive for research and development of new antibiotics. [80] In other words the large drug companies which specialize in the research and development of new medicinal drugs have found that the development of new antibiotics is not as profitable as the development of drugs used to treat chronic illness and other diseases. Patients only use antibiotics for a week or two, while a patient with a chronic disease will likely be purchasing pharmaceutical drugs for the rest of their life.[81] Antibiotic research is also less profitable because in the global market, doctors are beginning to hold new antibiotics in reserve to be saved for the most resistant infections. [82] Because this practice is beginning to become more popular, pharmaceutical companies fear that a new antibiotic may not be used frequently after its development and therefore, it will take longer to collect return on their investment. [83] Finally, when asked what could be done to encourage the research and development of new antibiotics, pharmaceutical and biotechnology companies have stated that the FDA's requirements for drug development change too quickly and greatly increase the cost of research and development. [84] These companies have continually requested a streamlining as well as a standardization of the FDA's drug approval policies.[85] Until these disincentives are addressed or new incentives are given, it is reasonable to assume that fewer and fewer antibiotics will be developed. In 1990, half of big medical research and development companies in the U.S. cut or significantly reduced their antibiotic development division. [86] Then, between 2000 and 2004, even more cuts were made by the companies who had continued to research new antibiotics. [87] It takes about ten years for an antibiotic to be discovered, tested, approved, and produced. [88] The considerable downturn in funds being invested now suggests that the next ten years will see the introduction of even fewer new antibiotics.

For decades, antimicrobial resistance has spread quickly in the United States.[89] This continual increase can be seen in Figure 2. This figure is a graph published by the Center for Disease Control (CDC) , a government agency that has compiled data which shows the steady increase in antibiotic resistance. The graph shows the percentage of three common bacterial infections that are resistant to an antibiotic commonly used to treat them. For example, the uppermost line shows the percentage of staph infections, caused by the bacteria staphylococcus aureus, that were resistant to methicillin in a given year. Enterococci are bacterium known to cause urinary tract infections and meningitis.[90] As one can see from the figure, until the late 1980's, all cases could be treated with the antibiotic vancomycin, but recently, strains of resistant enterococci, known as vancomycin resistant enterococci (VRE), have been found. Figure 2 shows that in the year 2000, a little more than twenty percent of enterococci infections were resistant to vancomycin. From the graph we can also see that after the year 2000, levels of methicillin resistance have increased to more than fifty-five percent. This means that more than half of all staph infections are resistant to treatment from methicillin, which was once the most effective antibiotic available in cases of staph infection. [91]

Figure 2



Infectious Diseases Society of America (2010). Retrieved from <http://www.idsociety.org/badbugsnodrugs.html>

Until recently, the spread of antibiotic resistance was not considered a serious threat because experts and government officials expected new antimicrobials to be developed as quickly as old drugs became ineffective.[92] Indeed, if antimicrobial resistance stayed at a manageable level and new drugs were continually put on the market, antimicrobial resistance would not become a serious threat. Unfortunately, the Infectious Disease Society of America (IDSA) reports that the supply of new and approved antibiotics has been steadily declining. [93] The IDSA is a group of concerned doctors, medical microbiologists, and public health workers. The association is concerned by the lack of new antibiotics being developed to treat new levels of antibiotic resistant infections.[94] The association reports that this year, more than two million Americans will contract a bacterial infection in a hospital and now, close to seventy percent of these infections will be resistant to antibiotics.[95] Because of the prevalence of resistance, ninety thousand of these patients will die as a result of their infections.[96] If nothing is done, the decade to come will be even worse.[97]

It is possible that government officials hold pharmaceutical companies responsible for the shortage of antibiotics and therefore, are reluctant to offer them incentives to fix a problem they allegedly created. However, the IDSA considers the shortage of new drugs a societal problem and one that requires collective action to overcome. The IDSA argues that large research and development corporations cannot be blamed for the current shortage of antibiotics. Pharmaceutical companies have a legal responsibility to pursue profit, not the public good. The IDSA argument is supported by U.S. court rulings which allowed shareholders to sue corporate directors because the director was using the shareholders' funds to pursue public health interests rather than high investment yields.[98]

Though the supply of new antibiotics is dwindling, the United States government has not placed any considerable restrictions upon antibiotic use. For a developed nation, the U.S. has an unusually large division between public-health agencies and individual care providers.[99] Public-health agencies, like the FDA (Food and Drug Administration) and CDC (Center for Disease Control) are better positioned to use collective rationale. They advocate the preservation and conservative use of antibiotics. Most doctors know that antibiotic use contributes to antibiotic resistance, but many are reluctant to reduce their use of antibiotics.[100] Congress has not granted the FDA or the CDC the power to regulate antibiotic use.[101]

The Center for Disease Control conducts surveys about antibiotic use within the United States as well as studies designed to determine antibiotic resistance levels among infectious disease. The Public Health Service Act of 1994 gave the CDC the power to quarantine those it suspects of having an infectious disease.[102] The CDC has not received the funding necessary to create and enforce rules regarding the hospital's quarantine of patients suspected of having an antibiotic resistant infection. [103] Legislation regarding isolation of patients known to be infected and the quarantine of those suspected of being infected is handled at the state level and there is a great disparity between the level of quarantine and isolation mandated by different states.[104] The CDC has not received funding sufficient to monitor antibiotic use. However, the CDC has published statements warning that serious action and commitment will be required when the U.S. decides to properly address the spread of antibiotic resistance.[105] Though it faces a lack of funding, the CDC has taken steps to prevent antibiotic resistance. [106] It has worked with other agencies as well as action groups to spread a public awareness campaign that outlines the problem of antibiotic resistance and encourages people not to misuse antibiotics. The CDC has also participated in efforts to develop an action plan that outlines the steps the United States should take when the federal government begins legislating institutional changes for the purpose of combating antimicrobial resistance. [107]

The lack of federal guidance combined with the inconsistency of state regulations has created a great disparity between hospital practices. Dr. Alan Zillich and colleagues conducted a survey of infection control staff in U.S. hospitals in an attempt to determine the level to which U.S. hospitals regulate antibiotic use. [108] The survey found that fifty-nine percent of surveyed hospitals followed guidelines for antibiotic use during surgeries. About half of the U.S. hospitals required physicians to get approval before using extremely potent antibiotics. Less than half of U.S. hospitals provided physicians with information about each other's antibiotic use. About one fourth of the surveyed physicians reported that their hospital used some sort of automated software to help physicians prescribe the correct antibiotic and monitor antibiotic prescriptions.[109]

In his Congressional Quarterly article, *Fighting Superbugs*, Clemmitt reports that antibiotics are overprescribed in the U.S.. Clemmitt claims that this is due in part to the fact that patients often consider antibiotics to be a miracle drug and therefore, when they feel ill they demand antibiotics from their physician. Clemmitt links this irrational demand to drug companies in the U.S. that use aggressive advertising campaigns to increase demand for their products.[110] Doctors have monetary incentives to keep their patients happy. It's also very easy for a doctor to give their patient antibiotics, while it is considerably harder for a doctor to diagnose a patient’s problem and then convince the patient they don't need antibiotics. Clemmitt cites studies which have shown that doctors are much more likely to prescribe antibiotics when they feel pressure from their patients to do so. He also cites studies which discovered that in the U.S., as many as nineteen out of twenty prescriptions for antibiotics are unnecessary and could be prevented by proper diagnosis and appropriate treatment. The result of all these unnecessary prescriptions is a flood of antibiotics being released into our hospitals and communities, this places extraordinary selective pressure on bacteria communities and the result is a continual increase in antibiotic resistance. [111]

Antibiotics are overprescribed in the U.S. but despite the unnecessary prescriptions, still more antibiotics are given to animals. It is estimated that seventy percent of antibiotics used in the United States are used on domestic animals.[112] A considerable number of those antibiotics are similar to those given to humans and therefore, some health workers worry that we are putting selective pressure on bacteria to become resistant to antibiotics even before the infections spread to people. [113] It was this fear which lead the European Union to ban the use of antibiotics as growth promoters in domestic animals if those antibiotics were similar to those prescribed to humans. [114] However, in the U.S., a considerable amount of controversy has developed around this type of legislation. Some have argued that the scientific support for the connection between antibiotic use in animals and antibiotic resistant infections in humans is too weak to warrant a ban.[115] They claim that the negative impacts of such legislation, for example, higher meat prices, will not justify any decrease in antibiotic resistance. [116] However, there are a number of scientists who cannot accept the idea that putting twenty-five million pounds of antibiotics into our livestock every year has little negative effect upon the local population of bacteria.[117] During the last decade, Congress has proposed legislation similar to that passed by the E.U. Those supporting this legislation cite studies which have identified three infections, Salmonella, Campylobacter, and E. coli, which physicians and veterinarians say are connected to antibiotic use among animals. [118] They also cite some worrisome reports by the United States Geological Survey which found traces of antibiotics in almost half of the U.S. streams surveyed. [119] Despite the support for this legislation, the United States has yet to pass legislation which restricts antibiotic use among animals and farmers are still able to give their animals large doses of antibiotics without a permit or prescription. [120]

Organizations dedicated to combating antimicrobial resistance have been frustrated in their efforts to persuade Congress to pass regulations aimed at preserving the effectiveness of antibiotics.[121] Since 2004, IDSA has been lobbying Congress to enact stricter regulations of antibiotic use. A few members of Congress have listened to the IDSA and introduced legislation which would enact the policy changes the IDSA recommends. However, the majority of Congress has been occupied with other issues and therefore, the legislation proposed by the IDSA has been ignored.[122]

The Netherlands

The Netherlands is a physically small nation which covers about 41,526 sq km. It is comparable in size to the state of Maine. However, it's population of more than fifteen million makes it one of the world's most densely populated countries.[123] The Netherlands takes a collectivist approach to the provision of health care. Everyone has access to healthcare, and the government subsidizes a considerable amount of the cost. [124] As a member of the EU, the Netherlands participates in a ban on giving certain antibiotics to animals. The antibiotics banned are antibiotics which physicians and microbiologists feared would contribute to a resistance that was transferable to humans.[125] The legal system of the Netherlands provides for the protection of physicians' independence.[126] However, the government organizations which monitor health care in the Netherlands have the authority to set hospital policy and demand physicians' compliance.[127] Hospitals in the Netherlands have a legal obligation to prevent the spread of infection between patients.[128] Hospitals are also required to participate in the national campaign to fight the spread of antibiotic resistant infection.[129]

The Netherlands has exceptionally low levels of antibiotic resistance. [130] For example, the incidence of MRSA colonization in Netherland's hospitals is roughly one percent, while surrounding countries see incidence levels between ten and forty percent.[131] The Netherland's success is credited to a national policy of restricting antibiotic prescriptions and mandating aggressive quarantine practices.[132] Much of the Netherland's search and destroy campaign is directed against MRSA (Methicillin Resistant Staphylococcus Aureus), an antibiotic resistant infection that is often resistant to multiple antimicrobial drugs and therefore threatens hospitals across the world.[133]

In a report which outlined the Netherlands model for infection control, A. Voss and J. A.J. W. Kluytina describe three government agencies which coordinate the country's efforts to minimize bacterial infection. These agencies are the Dutch Health Care Council, the National Institute of Public Health and Environmental Protection (RIVM) and the Working Party on Infection Control (SWAB).[134] The Dutch Health Care Council requires every hospital to employ a committee of infection control specialists. This committee is composed of infection control nurses who work under the guidance of medical microbiologists. These committees work within the hospital administration to ensure that the national guidelines for infection control are implemented. The committees also monitor antibiotic prescriptions and the spread of infection, work with physicians on cases of exceptionally life threatening infections, and assist with the disinfection of hospital rooms. The National Institute of Public Health and Environmental Protection collects data from these committees and compiles it to create a national report which describes national levels of infection, antibiotic use, and antibiotic resistance. The Working Party on Infection Control compiles literature on infection control, publishes the national guidelines for infection control, and provides a database of knowledge for physicians and infection control specialists.[135]

Hospital compliance with the national guidelines has been the key to the Netherlands success.[136] In a recent survey of ninety-two hospitals in the Netherlands, all were found to have a committee of infection control specialists. All but three of the hospitals were using a computerized tool, a formulary to determine how and when antibiotics should be prescribed. Many of the hospitals were also conducting educational meetings on antibiotic use and giving doctors feedback as to their success in preventing antibiotic resistance.[137] In 2008, the National Institute of Public Health and Environmental Protection (RIVM) and the Working Party on

Infection Control Strict reported that levels of antibiotic use had only marginally increased since the early 1990s. The report found the levels of resistance increased in proportion to the increasing use of the respective antibiotic. The report concluded that antibiotic use and antimicrobial resistance were both at sustainable levels[138]. Adherence to national guidelines has created a uniformity among infection control practices in hospitals within the Netherlands. The uniformity of infection control in the Netherlands allows for a detailed discussion of how a patient will be treated, that remains fairly accurate regardless of the hospital into which the patient is admitted.

Vos, et. al give a detailed description of how patients exhibiting Methicillin resistance are quarantined in the Netherlands. Upon admission to a Netherland's hospital, patients are categorized into three groups: those known to be carrying MRSA, those with a higher than normal probability of carrying MRSA, and those whose characteristics do not suggest a higher than normal probability of carrying MRSA. [139] A patient is placed in the first category once a test has confirmed that they have MRSA. Patients are placed in the second category if they have been, "Treated in a foreign healthcare institution; transferred from a medical center with an outbreak of MRSA not brought under control; had contact with an individual with proven MRSA colonization or infection; [or if they are] an adopted child from abroad." [140] A patient who is known to have MRSA is subjected to strict isolation.[141] A patient in the second category, who is suspected of having MRSA, is placed into quarantine until two different tests are completed. [142] If one of the tests returns positive, the patient becomes a confirmed MRSA carrier and is moved into category one and strict isolation, but if both of the tests return negative, the patient can be removed from quarantine.[143] Patients who fall into the third category are not quarantined upon admission.

When a patient is placed into strict isolation, they are put in single bed room. When possible, they are put in a room that has negative air pressure and an anteroom. [144] This means that the anteroom has lower air pressure than the hospital ward, and the patient's room has lower air pressure than the anteroom. Therefore, whenever a door is opened, air travels towards the patient's room, not away from it. This prevents the spread of airborne bacteria. The patient is assigned to a doctor and an infection control nurse. [145] In life threatening cases, the patient might also be placed under the direct care of one of the hospital's medical microbiologists.[146] Doctors and nurses attending the patient wear masks, gowns, gloves, and caps. After attending the patient but before leaving the anteroom, hospital staff must be thoroughly disinfected. Cultures are taken from the patients infection so that the bacteria can be identified. [147] Tests which reveal the genetic strain of bacteria are performed. [148] These tests are performed by an infection control nurse or microbiologist. Using these tests, doctors and infection control staff can determine the exact genetic makeup of each infection and then trace that infection to the hospital or community in which it originated. Sixty to eighty percent of MRSA infections are linked to hospitals outside of the Netherlands. [149] These tests also allow doctors to determine which antibiotics will successfully kill the bacteria, and which antibiotics the bacteria has resistance to. [150] The doctor can then consult a formulary to determine which of the available antibiotics should be used. [151] The formularies are designed to prevent overuse and misdiagnosis of antibiotics so that the local community of infectious bacteria will not acquire resistance at a threatening rate. The formularies are also designed to prevent important antibiotics from being overused. While in isolation, patients are washed with disinfectant daily and given the formula prescribed regimen of antibiotics.[152]Patients are held in strict isolation until six successive tests for MRSA have negative results. [153]

When it is discovered that a hospital patient who is not in quarantine has contracted MRSA, it is assumed that the infection has spread throughout the entire ward.[154] The entire ward is placed into temporary lockdown until every patient and staff member in the ward has been tested. [155]

There is a considerable upfront cost to pursuing such a zealous search and destroy policy. Some might assume that such a radical approach to combating antibiotic resistance does not make fiscal sense. An extensive cost-benefit analysis was conducted by Van Rijen and Kluytmans, two Dutch infectious disease scientists. [156] The study was performed in a Netherlands hospital, Amphia, and it revealed that the policy saved the hospital both lives and money.[157] In this study, Van Rijen and Kluytmans determined that the policy costs the Amphia hospital 215,559 euro per year. The majority of these expenses were the wages for the infection control committee. It was predicted that if the policy was not pursued, the hospital would pay 427,356 euro per year combating additional cases of MRSA. An average of ten patients per year die at Amphia because of antibiotic resistant infection. It was estimated that between eighteen and twenty seven patients would die each year if the policy was not pursued. Therefore, Van Rijen and Kluytmans claim that the hospital saved between eight and seventeen lives as well as roughly two hundred thousand euro per year. [158] Since sixty to eighty percent of MRSA cases in Dutch hospitals occur in patients who have been transferred from a hospital outside of the Netherlands, the cost of the Netherland's search and destroy policy would decrease considerably if all of the neighboring countries were to adopt a similar policy.

A Comparison Between The Netherlands and The United States

There are challenges to performing a cross case comparison between the United States' treatment of infectious disease and the Netherlands' treatment of infectious disease. In the U.S., there is such diversity between hospital practices that it is difficult to generalize and view the situation as a whole. In the Netherlands, strict adherence to national guidelines has created a uniformity among infection control practices. The uniformity of the infection control in the Netherlands allows for a detailed discussion of how infection is fought that remains fairly accurate regardless of the hospital. This type of discussion is not possible when examining the U.S. Other differences which complicate comparisons of national level policy include differences in society, population size, and geographical size.

Despite these difficulties, it easy to determine that United States and the Netherlands have significantly different approaches to fighting infectious bacteria. The Netherlands has adopted many of the design features which common-pool resource theory suggests are necessary for the successful governance of a commons. In the United States, the conditions are similar to those described around the occurrence of a tragedy of the commons. Therefore, it should not be surprising that the spread of antibiotic resistance is under control in the Netherlands, while antibiotic resistance is rapidly increasing in the United States.

In the United States, doctors have incentive to do what their patient wants, but they are rarely held accountable for many of the negative side effects the over prescription or misprescription of antibiotics has upon their community. In the Netherlands, doctors have incentive to do what is best for their patient, but they are often required to consult a formulary or medical microbiologist before prescribing antibiotics, and they are held responsible for their prescriptions. Medical microbiologists are further removed from individual patients. They are responsible for the health of their entire hospital. Therefore, they are better positioned to prescribe antibiotics in ways that are more rational for their community.

The Netherlands and the United States have very different levels of monitoring. In the Netherlands, every prescription is tracked. Hospital staff can access information regarding every doctor's prescription of antibiotics. Every hospital has an infection control committee which compiles data about the hospital's use of antibiotics and the hospital's population of infectious bacteria. This information is sent to the National Institute of Public Health and Environmental Protection which compiles this information into a yearly report that is available to everyone. The United States has no comparison. The Center for Disease Control conducts surveys about antibiotic use within the United States as well as studies designed to determine antibiotic resistance levels among infectious disease. However, these are surveys, not censuses, and the information is not used to hold hospitals to any standard.

Hospitals in the Netherlands have a much better understanding of how well other hospitals are controlling the spread of antibiotic resistance. One reason for this is the annual national report that documents antibiotic use and the prevalence of antibiotic resistance. Another reason is the tests performed by infection control specialists upon cases of antibiotic resistant infection. Because these tests are able to determine the exact genetic makeup of each infection and then trace that infection to the hospital or community in which it originated, they provide a level of peer-to-peer monitoring. Hospital staff know if the infection in their ward came from a neighboring hospital. They also know that if they lose control of an infection and the infection spreads to other hospitals, the other hospitals will hold them accountable. This information helps the staff of successful hospitals build trust between each other. This information also puts significant positive peer-pressure on irresponsible hospitals, giving them incentive to improve.

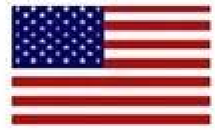
The combination of information on antibiotic use available in the Netherlands provides a level of transparency similar to that described by Ostrom when she examined successful water use governance institutions. According to her theory, transparency should provide hospital staff in the Netherlands with enough information to realize that collective action is working and the Dutch health institutions are keeping antibiotic use at appropriate levels. When an individual can see successful results coming from their participation in collective action, this, combined with the fear of being caught breaking rules helps to motivate compliance. On the other hand, the lack of similar transparency in the U.S. creates a situation in which doctors have little fear of being caught inappropriately prescribing antibiotics. Doctors in the U.S. also have few means of determining to what extent their peers are misusing the resource.

After considering the different levels of transparency surrounding antibiotic use, one should not be surprised to learn that the U.S. and the Netherlands have very different levels of antibiotic use. Indeed, just as common pool resource theory predicts, in the U.S., where individual doctors can use a common-pool resource with relative privacy and without detailed knowledge of their counterparts actions, the common-pool resource is being consumed in an unsustainable way. It is estimated that the United States should cut antibiotics prescriptions by as much as ninety-five percent.[159] At the same time, the Netherlands has reported sustainable levels of antibiotic use for more than fifteen years.

It should be noted that the U.S. and the Netherlands also have different approaches to quarantine. In the U.S., quarantine regulations are written by the states, and there is a great disparity between the strictness of state regulations. On the other hand, the Netherlands quarantine laws are uniform across the nation and the Netherlands has some of the strictest quarantine regulations in the world concerning antibiotic resistant infection. Strict quarantine and isolation help the Netherlands to limit the negative effects that antibiotics have upon the local community of bacteria. If an infection is isolated, antibiotic use may still cause that infection to become antibiotic resistant. However, as long as the infection is killed off entirely, its resistance to antibiotics will not spread to the community gene pool and negatively affect other patients. In other words, to the extent to which an infection is kept in isolation, the use of antibiotics on that infection will not affect the common-pool resource. The Netherlands aggressive quarantine regulations is one of the two reasons cited by the Working Party on Infection Control as the cause of the successful containment of antibiotic resistance in the Netherlands.

Figure 3 shows a comparison between the institutions in the U.S. and the Netherlands. Figure 3 is a summary of several of the key differences between the institutional approaches these countries take concerning antibiotic resistance. For example, the figure show that the U.S. allows antibiotics to be given to animals, while the Netherlands restricts the types of antibiotics which can be given to animals. This figure illustrates the claim that the U.S. has many of the conditions associated with a tragedy of the commons, while the Netherlands has adopted several of the recommended design principles for institutions tasked with the protections of a common-pool resource.

Figure 3
Comparison between the Netherlands and the U.S.



	The Netherlands	The United States
Prescriptions required?	Yes	Yes
Antibiotic use is monitored?	Yes	Rarely
Doctors are aware of other doctors use of antibiotics?	Yes	Rarely
Doctors are held accountable for antibiotic precriptions?	Yes	Rarely
Antibiotics can be given to Animals?	Some Antibiotics	Yes
Public health officials work side-by-side with doctors to fight infection?	Yes	No
Intensity of Quarantine Laws?	Very Strict	Varies by State

Policy Recommendations

Because antibiotic resistance is such a complex and multifaceted common-pool resource, and because it affects everyone, the primary organization to charged with combating increasing resistance should be the government. The Dutch government is an excellent example of how governments can address the threat antibiotic resistance poses to society. The U.S Department of Homeland Security, the CIA, IDSA, WHO, CDC, and ASM all agree that antibiotic resistance is a threat to national security in the U.S.[160] Because antibiotic resistance is a national security threat, which will affect millions of lives, governments should pursue an active role in combating the threat. While some hospitals may find it worthwhile to combat antibiotic resistance individually, we cannot take the risk that other hospitals will not. Also, there is little individual incentive for small private practices and farmers raising livestock to avoid misuse of antibiotics. Therefore, the U.S. government and governments like it need to take steps to protect the genetic makeup of infectious bacteria populations in a way that prevents or slows the increase in antibiotic resistance.

Common-pool resource management theory says that organizations can alter incentives in such a way that what is best for each individual is also best for the community as whole. This is done by first determining what the replenishment rate of the resource is. That information will help a society identify the maximum sustainable withdrawal rate. Then, the society should equitably allot rights of withdrawal so that the sum of all these is less than the maximum sustainable withdrawal rate. Some type of institution should be created to monitor withdrawal and impose graduated sanctions on those who withdrawal more than their allotment. The more transparent an individual's actions are, the more likely individuals are to comply with the established rules. Finally, it is best when the institution is made up of the people who are using the resource and those people have the power to democratically change the rules so that institution can adapt to changes in the resource or its users.

The Infectious Disease Society of America (IDSA) recommends that the U.S. create a Federal Office of Antimicrobial Resistance.[161] The purpose of this office would be to coordinate the efforts of an interagency task force to implement the CDC's proposed action plan.[162] Such an agency could also impose restrictions on antibiotic use. Restrictions on antibiotic use combined with a high level of monitoring, an important component of the CDC's action plan, could drastically reduce over prescription rates in the United States.

Determining the replenishment rate of a common-pool resource can be difficult. In the case of antibiotic resistance, the replenishment rate can be considered the rate at which new antibiotics, those to which infectious bacteria do not have resistance, are being developed. Once the proposed Federal Office of Antimicrobial Resistance determined the rate at which new antibiotics are being produced, it would have a sense of how stringently it will need to regulate use of the antibiotics currently available. The slower the development of new antibiotics, the lower the sustainable use rate of antibiotics will be.

In the Netherlands, antibiotics are still given to every patient who needs them. Doctors are required to use tests and cultures to prove the patient has a legitimate need and the proposed prescription is the appropriate one. Ideally, this is all that will need to be done in the United States. If it is true that close to ninety-five percent of antibiotic prescriptions in the U.S. are unnecessary, then simply requiring that doctors prove their patient needs the antibiotic being prescribed could reduce antibiotic use to sustainable levels. However, if the supply of new antibiotics continues to decrease, there may eventually be a day when antibiotics need to be saved for cases of life threatening infection. Either way, it seems logical for the appropriation of antibiotics to be on a level of need basis, with the newest and most potent antibiotics being reserved for the most resistant and/or life threatening cases.

The requirement that Dutch hospitals hire an infection control team has proven to be a successful policy and one the U.S. government should consider adopting. An infection control team does not work for an individual patient, and therefore, they are further separated from the individual incentive to overuse antibiotics. These committees work for the government, and as public health workers, they are well positioned to act in a way that is collectively rational. However, these workers are also working on the frontlines, in the hospital wards. They are helping doctors determine the correct prescription, monitoring antibiotic use, and reporting on levels of antibiotic resistant infection. To some extent, these committees accomplish what common-pool resource theory recommends when it advises that those using the resource should also be the ones monitoring resource use and making recommendation for change in the institutional rules.

Finally, the U.S. should follow in the Netherland's footsteps and mandate aggressive quarantine laws. Dutch microbiologists cite strict quarantine and isolation as a key strategy for limiting the negative effect antibiotic use has upon the local community of bacteria. If an antibiotic resistant infection is isolated and killed, its resistance to antibiotics will not spread to the community gene pool and negatively affect other patients. To the extent to which an infection is kept in isolation, the use of antibiotics on that infection will not contribute to an increase in the likelihood of antibiotic resistance in future infections. Making hospitals legally and fiscally responsible for antibiotic resistant infections acquired at their hospital would be an excellent form of graduated sanctions for hospitals which disregard quarantine laws. If hospitals lose control of an infection, they would be required to compensate everyone in their hospital to whom the infection spread. This would give hospitals considerable fiscal incentive to use strict quarantine procedures. The more threatening the infection, the greater the incentive to control it would be. The cost and benefit analysis performed in the Dutch hospital Amphia proves that strict quarantine and intensive monitoring of antibiotic use can save both lives and money. The greatest source of antibiotic resistant infections in the Netherlands is patients being transferred into the country from foreign hospitals. Because the U.S. is much larger country, it can be assumed that a much smaller percentage of patients in the U.S. were transferred into the country from foreign institutions. If this is true, then a search and destroy policy in the United States could be even more successful than the practice was found to be in the Netherlands.

A Call to Action

If antibiotic resistance continues to spread, countries such as the U.S. could face a tragic scenario in which treatable bacterial infections become untreatable, as they were before the invention of penicillin. Societies cannot continue to overuse antibiotics, as they have done with penicillin. The supply of new antibiotics is dwindling and the number of antibiotic resistant bacteria continues to grow. Therefore, societies need use the antibiotics they have in a sustainable way so that the growth of antibiotics resistance does not outpace the discovery of new antibiotics. Antibiotic resistance is a complex and multifaceted problem.[163] However, one can find guidance for combating this problem by looking at the theory developed around the governance of the commons. This theory shows that incentives must be altered so that individual incentives align with what is best for the community as a whole.[164] While some hospitals may find it worthwhile to combat antibiotic resistance individually, and this is the ideal situation, societies in which antibiotic resistance is growing rapidly cannot take the risk that some hospitals will not use antibiotics responsibly. Therefore, governments need to take steps to protect the genetic makeup of infectious bacteria populations in a way that prevents or slows the increase in antibiotic resistance. These institutions can prevent a tragedy of the commons by following the guidelines provided by Eleanor Ostrom and other common-pool resource governance experts. These experts tell us that individuals can come together to keep antibiotic resistance from spreading through collective action to create rules of use, implement sanctions, and monitor in a way which gives doctors and others sufficient incentive to use antibiotics in a collectively sustainable manner.

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