TRANSFORMATION OF MEDICAL TECHNOLOGY, INNOVATION, AND UNDERSTANDING FROM ANCIENT PLAGUES TO THE MODERN PLAGUE

Written by: Emma Chau, Olivia Dods, Neha Jag, Harshini Mohan, Rahul Naveen, Prerana Rao, and Sasha Xu (Oak Park High School, Oak Park, California, United States of America)

Introduction: Composed by the entire team

Since the beginning of human history, plagues and epidemics have widely affected global populations. Medical technology and innovation have been transformed by understanding the evolution of pandemic disease through the years, from the first outbreaks of ancient plague to the proliferation of the modern pandemic. The study of epidemiology has changed greatly over the course of history. The extent of medical knowledge was limited during the First Plague, consisting of largely provincial ideology. Through the course of subsequent outbreaks, however, analysis of these diseases has led to modern treatment practices that have improved contemporary medicine. In light of the current coronavirus pandemic, the information we have gained from the study of past epidemics has allowed us to tackle the global situation with more expediency and ability than we historically have been able to. Across the globe, populations, cultures, and societies have been shaped by the dissemination of disease in tandem with the propagation of medical knowledge. This evolution of knowledge and its effect on modern culture can be mirrored in the current situation of COVID-19. Through global communication, cooperation, and the sharing of medical innovation only can this generation of mankind overcome the repercussions of a global pandemic. By harnessing the power of the planet's scientific successes, the history of plague can be applied to the present condition in surmounting the daunting task of elevating public health and situational awareness.

To explore the transformation of medical developments from the ancient to modern plagues, we discuss the historical context of plague and transmissible diseases and the innovations that our understanding has led to.

Medieval Treatments and Reactions to the Plague: Written by Prerana Rao

The infamous Black Death was a plague that consumed the world in the 1300's leaving chaos in its path as no one had experienced a pandemic of such intensity before. It hit in three different waves throughout the span of 1300 to 1900's. The first plague was in Europe, and lasted from 1347 to 1351. In just this short period of time the plague managed to wipe out around two-thirds of Europe's population. A reason behind the rapid spread and fatality of the plague was the inexperience of doctors. When the plague hit Europe, the majority of medical knowledge was developed through philosophical and religious means: "14th century medical theory and practice centered on the theories of the 4th century B. C. E. physician Hippocrates and the philosopher Aristotle as well as the 2nd century B. C. E. physician Galen"(*The Medical Response to the Black Death,* 25). In combination with the lack of knowledge about the human body, physicians were also unaware of the scientific cause behind the plague. Many referenced the Bible, in which stated that previously when Egypt suffered plagues centuries ago, they were sent down by God to rid the Earth of sinful humans. Other physicians hypothesized that the plague was as a result of poor air quality otherwise known as miasma. This poor air quality could be contributed to the work of celestial bodies beyond human control. This poor air quality offset the balance of the human bodies' humors.

The humoral theory was a popular theory that combined the minimal knowledge of human anatomy doctors' had, with philosophy. Doctors believed that the crucial aspects that made up the Earth existed within humans, and the four elements, fire, earth, water, and air, took refuge within the human body in certain forms. Humans' bodily fluids were linked to the

elements, fire being associated with yellow bile, blood being air, phlegm being water, and black bile being earth. It was said that illness struck an individual when the balance of these four humors was upset, subsequently leading many to believe that a shift in nature is what caused the plague to spread among millions. A form of medicine accounted for the humoral theory, stating that activities that would heat up or moisten the body should be avoided. Individuals should avoid hot baths and physical and sexual activities. People were advised to adjust their diet and stray away from moist foods like fish, and keep their eating in moderation. This is what doctors advised people to do as a daily routine to maintain their overall health. However the actual treatments for the plague varied, from limiting exposure to wind, to animal cures, to pulse reading and uroscopy, and lastly several forms of "potions".

Returning back to the idea of miasmas, many physicians emphasized the importance of limiting exposure to south winds which apparently contained the poorest air. Many strayed away from marshes, coasts, and would tightly seal the doors of their house. Additionally an idea akin to wearing masks came about. Many would also burn incense such as juniper, ash, vine, or rosemary. As for treatments for those who already had the plague, many doctors turned to animal cures. The most popular one was the vicary method, which involved stripping the back of a chicken bare and then rubbing the chicken onto affected areas. Others would turn to chopping up snakes into small pieces and applying it to the buboes or swollen areas. Other treatments that were used in conjunction with each other were the uroscopy and pulse reading. Many patients would have their urine analyzed, from smell, to look, to even taste. Another form of diagnosis was the pulse reading that identified various types of heartbeats and subsequently gave doctors an idea of whether a patient was afflicted with the plague. Another popular form of treatment

was the making and consumptions of potions. As many believed there were religious aspects to the plague, physicians also used symbolic properties of certain elements in potions as a futile attempt to cure a patient. Crushed up emeralds were made into a mixture and given as medicine. A very popular concoction during the time was the "Four Thieves Potion" which was a combination of cider, vinegar, or wine with spices such as sage, clove, rosemary, and wormwood (*Medieval Cures for the Black Death*). Physicians even preached the healing properties of gold, claiming all pieces of gold contained a bit of the sun in them. Bathing in gold was a way to rid all illness and fill one's body with the sun's purity.

Evidently, looking back on these treatments, one could guess that they were wildly ineffective. However odd, people were desperate to attempt any method that would rid them of their illness. Because many doctors were either able to attend university or were apprentices, they had an inane amount of credibility, considering their medical knowledge was from religion and astrology. To be able to develop an effective treatment, doctors needed to understand how the plague was created, how it spread, and understand human anatomy. The cause of the plague was not some spiritual massacre sent down by the Gods but a strain of bacteria known as *Yersinia pestis*. These bacteria lived within the stomach of the fleas *Xenopsylla cheopis* and the fleas were transported by rats. Whenever human interaction with rats occurred, the fleas could easily travel to humans, and the bacteria within the fleas could pass through the broken human skin that resulted from a fleas' bite. The symptoms of the plague would start off with a blackish blister or pustule at the site of the bite. Then the lymph nodes would swell around the armpits, neck, or groin, resulting in large and incredibly painful swellings on the skin called buboes. Subcutaneous hemorrhaging would occur under the skin and this hemorrhaging caused damage

to the nervous system that later led to psychological problems. Many experienced vomiting, coughing of blood, high fever, diarrhea, and pneumonia in conjunction with this. While physicians were unable to develop cures to reduce the symptoms of the plague, credit can be given to the development of public health during that era. One effective method to contain the plague that developed during the Black Death was quarantining. Doctors observed that often when ships arrived at ports, they were the main carriers of the plague, and as such were forced to isolate themselves at the port for forty days after arriving. Many times doctors would visit cases where people were suspected of carrying the plague and then put those families in isolation. Hospitals were sanctioned into areas where those with a fever were isolated from other patients. These public health measurements were effective enough that they are still in place today, especially as we live through another era of a great pandemic.

Shift in Thinking from First to Second Plague: Written by Sasha Xu

The Plague of Justinian, also known as the first plague, was the first well documented case of bubonic plague. It was later identified to be caused by Yersinia pestis and was mainly transported by rats. The Plague of Justinian received its name from its association with the Byzantine emperor Justinian I, whose empire was greatly affected by the plague. As told by Procopius, Justinian I's court historian, the plague was believed to have been the wrath of God. He believed that God highly disapproved of the ruling of Justinian I, who prioritized his own power at the expense of his people. Throughout the plague, the emperor demanded tax collection to continue and raised the prices of the taxes in order to fund his own projects. He did not extend any help to the sick and dying, nor did he take any measures to stop the spread of the plague (Mark).

Procopius notes that since there was so little understanding of the disease at the time, there was no way to stop it except through religious rituals. Because of the lack of knowledge surrounding the plague, the people of the time contributed it all to the workings of God. Procopius wrote about how many people reported seeing apparitions of supernatural beings right before being infected with the disease, or how they were visited by visions in their dreams, warning them of their death. Eventually, the people began social distancing and quarantining to slow the spread of the plague; however, Justinian I had no influence on these measures (Mark).

The Second Plague, also known as the Black Death, was the most infamous and deadly plague of the medieval time period. It mainly affected Europe and caused approximately 30 million deaths there, but about 50 million worldwide. The Black Death was caused by all three

types of plague and spread primarily through rats and various insects (Mark). Similar to the First Plague, there was a lack of understanding of the causes of plague. Medieval chroniclers understood that the plague was contagious but could not conceptualize the vectors that spread the disease (Dewitte). Because of the lack of reasonable explanation, people were quick to attribute the explanation to God's doing, much like the Plague of Justinian. The three main views of the plague were based on the three main religions and generally fall into beliefs held by medival Christianity and Islam. Christians believed that the plague was punishment for their sins, "bad air," or various other superstitious reasons. They acknowledged that the plague was contagious, but believed it could be stopped through religious and superstitious practices. Many also fled the area to uninfected areas, believing that would benefit them. Muslims thought that the plague was gifted from God to provide an opportunity for martyrdom and that they should not enter or leave infected regions. They didn't believe the plague was contagious because they thought it only affected people God specified.

When their religious practices failed, the continuation of the plague led the people to lose faith in God, leading to the decline of the medieval Church's power. People began blaming the devil and minorities such as the Jews, as well as God, for their suffering (Mark). Rumors began circulating that the deaths of the plague were caused by a conspiracy of Jews to poison Christendom. This led to thousands of Jews being butchered, tortured, and incriminated, which led to an increased hatred of Christianity ("The Black"). This plague was the first to promote violent responses against others. Eventually, the plague passed and many believed it was also God's doing. Despite this, the lack of relief from God resulted in a questioning of faith and a different understanding of Christianity.

In conclusion, the main shift in thinking from the first to second plague was the religious beliefs. Throughout the first plague, the people unquestioningly upheld their faith in God. In the second plague, there is a shift from blind faith in religion to accepting other explanations for plague.

Modern Medical Analysis of Past Plagues: Written by Harshini Mohan

The way in which plagues (and epidemic diseases in general) is viewed has changed drastically from the first ever documented diseases to present day. Currently, the world is in a state of heavy analysis because of the current Coronavirus, which has greatly affected the general population. As scientists study how this virus specifically is affecting our population, they also will look to the past to analyze the behaviors and responses of people during periods of disease. By analyzing the way diseases have spread as well as the way in which medical professionals have responded to the diseases, we can learn a lot about how to adjust and change our perspective so that the approach to any kind of epidemic disease can be faced in the most efficient path possible.

To start, it is best to understand how plagues were viewed in the past, focusing on how "healers" may have viewed the disease in regards to symptoms, treatment options, and overall severity. When looking at how medical organizations looked at the plague that appeared in the mid 1300s (also known as the Bubonic Plague or the Black Death), there is more written about the relationship between planets, types of vapors that were spewed around into everyone's bodies, and general corruption of air and water (Hoeniger). In this report written by the Paris Medical Faculty, the doctors attribute the cause of the plague to a universal and a distant (astronomical) cause. To quote specifically, the faculty says that "the distant and first cause of this pestilence was and is the configuration of the heavens… a major conjunction of three planets in Aquarius" (Hoeniger). While some modern practices of medicine rely on the science of

astronomy when it comes to bodily cures and issues, most Western practices will not attribute diseases and illnesses to the position of the planets.

When examining how common folk viewed the plague, excerpts from Daniel Defoe's *A Journal of the Plague Year* prove useful, especially when looking at the interviews Defoe conducted. The speaker in Defoe's novel, signed H.F., asked commoners how they felt about the plague to which many asked back more questions, instead of stating their feelings and thoughts. They asked H.F., "Is God displeased with the immorality of Charles II's court? Is He demanding the courtiers pray for forgiveness and mend their sinful ways?" (Braudy). It is evident that the common people viewed the plague as a punishment from God for something they may have caused (indicating a permeating feeling of guilt and discomfort through London), rather than a potent and harmful biological virus.

When present day health care professionals view both ancient and modern plagues, the commonalities they find are rooted more in earthly conditions, rather than a religious or more abstract view. For example, an article written by the National Institute of Allergy and Infectious Diseases (NIAID) discusses the shared determinants of a plague occurring in 430 B.C. and the influenza of the early 1900s. In this article, the writers discuss how "international trade and troop movement during wartime played a role in both the emergence of the Plague of Athens as well as in the spread of influenza during the pandemic of 1918-19" (Study of Ancient and Modern Plagues Finds Common Features). The article goes on to state that seemingly unrelated issues like "poverty, lack of political will, and changes in climate, ecosystems and land use" can be factors that play a significant role in emerging epidemic diseases. When looking at how NIAID presents the cause of epidemics, their view is similar to that of the Paris Medical Faculty. Both

say there is a near cause and a distant cause. However, in NIAID's report, the authors accredit the "near" cause (specifically for the Bubonic Plague of the 14th century) to the specific bacterium, *Yersinia pestis*. They accredit the "distant" cause to the "complex and not fully predictable interactions between the disease-causing microbe, the human host, and multiple environmental factors" (Study of Ancient and Modern Plagues Finds Common Features). While these two reports are similar, the near cause of the Paris Medical Faculty is closer in description to the distant cause of the NIAID's report. This being said, it is safe to assume that in current studies of past plagues and epidemics, scientists and medical professionals specifically have focused on the more tangible aspects, such as environmental conditions and biological sciences.

In conclusion, the view of epidemic diseases, with a focus on historical plagues, has changed greatly from the first recorded instances to modern reflections. This change can be accredited to the advancements in various scientific fields, such as molecular biology and ecology. From these advances, scientists have been able to pinpoint specific changes, such as in DNA for example, that show why a human's conditions have changed. While the use of astronomy in human medicine has decreased greatly when it comes to Western practice and application, the world will continue to evolve. It is very feasible to say that the current view of medicine will be quoted as "outdated" or "abstract" by professionals in the future, just like how we view past diseases now.

Current Scope of Medicine in Regards to Transmissible Diseases: Written by Emma Chau and Rahul Naveen

Transmissible diseases, also known as communicable or infectious diseases, are illnesses that result from the infection, presence, and growth of pathogenic biologic agents in an individual human or other animal host. These diseases can be spread in several ways, including contact with bodily fluids, exposure to contaminated surfaces, consumption of food and water, respiration of airborne viruses, and infection by insect bites. In order to diagnose an infection, there are five criteria to be considered: an infection agent, a reservoir, a mode of transmission, a route of entry, and a susceptible subject who becomes infected with the virus. Infectious agents fall into five categories -- viruses, bacteria, fungi, protozoa, and helminths -- that infiltrate a living system and infect their host. These agents normally live, grow, and multiply in habitats known as reservoirs, which include humans, animals, and the environment. Humans can contract disease through five main modes of transmission: direct and indirect contact, oral transmission, respiratory transmission, and airborne transmission. Disease will enter the body by inhalation, skin or eye absorption, injection, and ingestion. Once inside the body of a susceptible subject, the virus will multiply, and the body will be damaged to the point where infection can be diagnosed.

Prevention and treatment of communicable diseases is a dual responsibility that must be tackled by both individual precautions and global safety measures. This is critical to keeping communities, nations, and global populations healthy and secure during times of epidemic outburst.

Disease control can be narrowed down to vaccines and medicines, specifically antibiotics and antivirals, and the respective new treatments in the medical field. A discussion of vaccines and medicines in modern context introduces pharmaceutical biochemical approaches to disease prevention and treatment through evolving relationships between microbes and human hosts. Vaccines are biological preparations that serve to improve immunity to a particular infectious disease by injecting agents of weakened or killed strains of microorganisms of a particular disease-causing toxin into the body. These agents stimulate the body's immune system by triggering a response that causes the body to react to the foreign pathogen as a dangerous virus. Although the vaccine does not inherently cause disease, it allows the body to create the antibodies necessary to destroy living strains of that same pathogen if it were to proliferate in the host at a future time by remembering the virus' respective antibodies. Hence, the body creates a defense mechanism to prepare for a potential response to living pathogens more proactively, since the necessary antibodies are created by using this "kick-starter" vaccination. The effectiveness of vaccinations is evident in the United States, where common viruses such as polio, measles, diphtheria, whooping cough, mumps, tetanus, and meningitis have been largely reduced or eliminated. This is due to the fact that those who are inoculated produce antibodies that neutralize disease-causing bacteria, making them less susceptible to infection and transmission of that disease. Hence, those who are unvaccinated are at a lower risk of infection because of what is deemed "herd immunity," since the likelihood of the vaccinated people in their communities becoming sick and transmitting the disease is reduced greatly when the large majority is vaccinated. The higher the percentage of vaccinated individuals in a community, the lower the likelihood that those at risk will come into contact with an infected individual.

In contrast to vaccinations that prevent disease, antibiotics and antivirals are measures of disease treatment that regulate the public health of communities. Antibiotics are powerful medicines that fight bacterial infections by either killing bacteria or stopping reproduction and proliferation of pathogens, and allowing the body's natural immune system to destroy invading bacteria. When taken according to prescription, antibiotics can save lives, but growing antibiotic resistance is causing the effectiveness of these medicines to decline. Taking antibiotics as directed, even after symptoms disappear, is necessary to cure an infection and prevent the development of bacterial resistance to these medicines. Antivirals, however, work against viral infections like the cold or flu, and fight infection by inhibiting the virus' ability to reproduce or by strengthening the body's immune response to infection. While antibacterial drugs cover a wide spectrum of pathogens while antiviral medications are used to treat a narrower range of organisms. Influenza, HIV, herpes, and hepatitis B can be treated with antivirals, though even these viruses can mutate over time and develop resistance.

In considering new treatments, modern medicine must discover new kinds of antibiotics and antivirals to treat drug-resistant infections, but the options for new treatment are slim because of antibacterial resistance. Pharmaceutical companies limit interest in resources to the antibiotic market because short-course drugs are not as profitable as those that treat chronic conditions and lifestyle related ailments like hypertension. Research is also expensive, risky, and time consuming, and return on any investment is unpredictable, because growing resistance eventually makes drugs less effective over time. Antiviral drugs are also in short supply because they are far more difficult to develop than antibacterials and cause damage to the host cells where pathogens reside.

To help with the development of new programs to stimulate research and development of new vaccines and medicines, The US Department of Health and Human Services recently formed a Biomedical Advanced Research and Development Authority that provides an integrated and systematic approach to the development and purchase of novel vaccines, drugs, therapies, and diagnostic tools necessary for public health emergencies. Additionally, Cures Acceleration Network provision of the Patient Protection and Affordable Care Act, signed into law by President Barack Obama, was designed to move research discoveries to safe and effective therapies by awarding grants through the National Institute of Health to biotech companies, universities, and patient advocacy groups. Non-profit organizations dedicated to accelerating the discovery and clinical development of new therapies to treat infectious diseases are bringing together philanthropists, medical research foundations, industry leaders, and other key stakeholders to forge effective solutions.

Despite the many recent developments that have been put in place to protect against disease, the individual can provide some of the strongest defenses against infectious diseases through their daily habits in the present day. Though these may seem like simple tasks, habits such as proper hand-washing, careful food preparation, and caution around wild animals and insects ensure that one reduces their exposure to harmful bacteria and disease. However if infection occurs, testing, routine immunization, and hospital visits for treatment ensure that the risk and spread of disease is minimized.

Additionally, modern disease regulation is largely configured by government policies that keep countries safe through well coordinated programs that monitor public health. A system aimed at improving public health and that serves to safeguard and elevate community health and

response to infectious disease threats must, therefore, be heavily reliable. U.S. public health surveillance provisions occur in a systematic process. Health care providers first report cases of notifiable transmissible diseases to state health departments, upon which officials verify these reports, monitor disease incidence, and identify possible outbreaks. This is then sent to the Center for Disease Control (CDC) and other federal organizations that independently gather and analyze information for disease surveillance. While this system is largely effective, innovative proposals have been made to increase surveillance efficiency by implementing a national electronic infectious diseases reporting system using automated laboratory reporting or systematic collection of informal disease reports from the Internet. Many also push for funding the entire public health system, as it has been radically underfunded in comparison to biomedical research. Another proposal is centered around the concept of syndromic surveillance, or real-time monitoring of nonspecific pre-diagnostic signs of disease outbreaks. This method is being explored by cities and states the federal assistance as a way to provide warning for future pandemic outbreaks. It would also implement systems to monitor school and work absences, over the counter medication sales, 911 illness calls, and patterns that suggest outbreak.

International cooperation is essential to national disease control because disease does not pay attention to national borders or ethnic differences -- everyone is susceptible to pandemics. The highly connected and readily traversed global village of our time means that one nation's problem soon becomes every nation's problem. The strategies already described must be implemented in order to have a true, lasting impact. Global surveillance is a critical component to responding to infectious disease worldwide. Currently, the strongest measures and guidelines promoting worldwide infectious disease surveillance are WHO's International Health

Regulations: these require member states to report certain diseases and outbreaks that may represent public health emergencies of international concern to the WHO and strengthen capacity for public health, surveillance, diagnosis, and response. The CDC's Division of Global Migration and Quarantine have developed an integrated and comprehensive partnership of local, national, and global health authorities that are working to prevent, detect, and contain infectious diseases in countries of origin and at U.S. ports of entry. Technological advances in disease surveillance and detection -- such as regional syndromic surveillance, bioinformatics, and rapid diagnostic methods -- have also strengthened infectious disease control and prevention efforts. Other networks are responsible for listening to "viral chatter," or the seemingly commonplace transmission of animal viruses to humans in parts of the world where the two populations overlap, such as live-animal markets or urban areas carved out of tropical rainforests. Identifying viruses, bacteria, and parasites in animals where they naturally live, and monitoring those organisms as they move from animals to human hosts is allowing scientists to discover that it may be possible to prevent deadly new infections of animal origin from entering and racing through human populations.

Though advances in disease surveillance has helped worldwide, the gaps in life expectancy between the richest and poorest countries now exceed forty years. This gap in life expectancy is in large part due to the toll of infectious diseases. Safe water supplies, sewage treatment and disposal, improved food safety, and vaccination programs are desperately needed in developing nations. However, the weakness of public health systems in resource-poor countries hinders efforts to immunize, treat, and monitor the status of patients. These countries lack disease surveillance programs and up-to-date laboratories, which are essential to find,

diagnose, and contain infectious diseases. In a similar way, life-saving vaccines and medications are not distributed equitably around the world. For example: half of those suffering from HIV/AIDS who need drug treatment are not receiving it, and two percent of people with multidrug-resistant TB receive the right medications. Unfortunately, this is due to the fact that drug research and development is not geared towards the needs of people in poorer countries because poorer countries are not a large market. Instead, the money spent on worldwide healthcare research is dedicated to problems affecting a smaller percentage of the world's population -- first world countries. Efforts are being made by foundations, pharmaceutical companies, and other organizations to overcome these challenges, providing funding, research, and medical resources to third world countries. This tragedy of global infectious disease is not only that so many lives are lost or damaged, but that so many of these infections could be prevented effectively if resources are properly allocated.

The Inside View on Epidemics and Plagues: Written by Olivia Dods & Neha Jag

Concerning the evolution of medical technology, innovation, and understanding between the first outbreaks of plague and the emergence of COVID-19, one must gain an insight into the field of medicine as it is experienced by medical professionals themselves. Organizing interviews with medical professionals such as Pharmacists, Nephrologists, and Physician Assistants has provided us with an unbiased and focused view on the impact of our topic, Epidemics and Plagues in medicine, on the medical field itself. We interviewed a medications expert, Dr. Manyak Pharm. D., a pharmacist who deals with prescription medication. Then, we chatted with a nephrologist, Dr. Eric Tong, MD, who specializes in treating kidney patients. Thirdly, we interviewed Mrs. Olivia Ray MMS, PA- C, who attended PA school with Wake Forest School of Medicine, graduated with her degree, and is now actively searching for job opportunities.

To look specifically into the comparisons between Covid-19 and other pandemics, such as the Black Plague, we first began by examining the influence that COVID-19 has had on medical professionals. When we first asked Dr. Tong, a kidney doctor, he described to us that "five months ago, [his facility] began to move patients to virtual. [They had] been doing [about] 20-25% virtual before that, but now [they] wanted to reduce traffic". He went on to say that they wanted to ensure proper staffing, as this unprecedented time brings uncertainty with patient visits. To make sure of this, Dr. Tong's facility always has "backup doctors and tag teams with other physicians" to treat all their patients. In addition, he describes that there has been an increase in PPE usage, while witnessing a decrease in patients coming in for lab testing. According to Dr. Manyak, her profession is "seeing less patients inside the pharmacy and

sending out more medications". However, she has been noticing that "doctor's offices have been overwhelmed and are not getting back to [them] as quickly". Mrs. Ray's PA education was coming to a close when COVID hit and because her second year of schooling was so dependent on "clinical experience, requiring patient interaction" she observed that plans were constantly changing. Furthemore, Mrs. Ray tells us, COVID-19 has made it "difficult to find employment" especially as a "new graduate."

Regarding the connection between COVID-19 and the overall number of patient inflow into medical facilities, we asked if these medical professionals saw an increase or decrease number of patients with unrelated health issues. Dr. Manyak expressed that she has seen "no change" in the numbers of patients visiting her pharmacy. She makes a valid point telling us that in "the world of pharmacy" people will always need their "chronic medication" promptly and on time as usual. Dr. Tong expressed a similar observation, in some instances there has been "a rare delay of care" but in the delicate field of nephrology, patients must regularly receive life saving treatment no matter the circumstances. He did mention that this "delay of care" has been an issue in other parts of the country as seen in Mrs. Ray's emergency department. During Mrs. Ray's final rotations in Neurology and General Surgery, she saw that not only were "planned admissions and treatments" postponed, but also that fewer patients were being admitted to the Emergency Department overall.. For example less patients came in for "abdominal, gallbladder, and appendix surgeries" and those appointments such that could be postponed, were rescheduled as "elective procedures" were cancelled at the time.

In order to compare the aspects of the COVID-19 pandemic and others such as the Black Plague, we found it important to look into specific trends in the medical field. Dr. Tong

described his work as “quieter” than before, with many elective surgeries being postponed. However, it seems that these numbers are increasing once again. As for Dr. Manyak, her pharmacy is “getting more frantic calls from patients who are afraid of getting sick”. They are also spending more time “reassuring patients and trying to provide personal protective equipment” to high risk patients”. On the other hand, Mrs. Ray has not seen any new trends in her work in relation to the Coronavirus.

Sustaining our investigation about new innovations in medicine, we then queried these individuals how medical technology has changed or improved since the start of this COVID related pandemic. Dr. Tong explained that he saw a slight improvement in telemedicine and a majority of his hospital’s patients, about “70%-80%” have moved to virtual visits. While there has been major improvement in COVID-19 testing, Dr. Tong feels that a significant challenge is limited “coronavirus testing” as the tests occasionally run out. Dr. Manyak feels there hasn't been a significant improvement, but she highlights that “masks, hand sanitizers and gloves are now more readily available” to all.

Change occurs inevitably, sometime for the better and sometimes for the worse. We wondered if our medical professionals predict that COVID-19 will have the power to change medicine tactics in the future. Dr. Manyak predicted that this is “most likely” as now there are precautions in place to ensure “necessary equipment” is distributed “in an expedient manner” and “ the data we gather is freely shared on a global level.” Dr. Tong agrees, telling us this will bring “more awareness to pandemics” and these increased levels of caution could “reduce flu” cases worldwide, as seen in Australia. Although, he is concerned that COVID-19 will delay future crucial drug trials. Mrs. Ray believes there will be more efforts for research that will

“prevent future infections” and that “social-distancing and masks” will continue to be pertinent measures taken to combat any contagious illnesses.

Connecting our knowledge of the Great Plague with our current knowledge of COVID-19, we contemplated on what makes the coronavirus unique in how it transmits in comparison to older viruses such as the plague. Mrs. Ray informed us that COVID-19 is “transmitted by respiratory droplets in the air” while the plague is a “bacterial infection” caused by the prokaryote Yersinia Pestis and transmitted by “rodents, animals, and humans.” What makes the coronavirus so unique is the virus’ variety “of clinical presentation” as symptoms range from “no symptomes to very severe symptoms.” Dr. Tong elaborates on this, expressing that “a big issue” with COVID is that many “spreading it … are asymptomatic” and the virus is spread in confined areas such as “churches, bars, and karaoke places.” He believes the virus is similar to “influenza” or the “common cold” than it is to the plague. Mrs. Manyak believes the two illnesses are incomparable as today we have treatments for the plague that result in “higher survival rates” while in the past there was much to be discovered about “science and medicine.”

As we have witnessed, finding a vaccine to treat COVID-19 has been difficult. We talked to our three interviewees to understand what elements are contributing to this. Dr. Tong shed light on this issue by explaining “it takes at least two years to formulate a vaccine, then it needs to be tested, and distributed”. He also goes on to discuss that there have been many failures in past vaccines, so the process is not a straightforward one. Dr. Manyak compares COVID-19 to the Black Plague, which was a bacterial infection treated by antibiotics. It is also very difficult to produce because “viruses mutate at a very rapid rate”. Mrs. Ray describes the Coronavirus as “a novel virus that [they] haven’t seen before”. She also goes on to comment about the fact that the

“whole world is working on and expectantly waiting for the same vaccine to prevent worsening of a pandemic”.

Closing out our interviews, we asked our interviewees how they think the use of medicine to treat viruses and epidemics has changed from past times to the 21st century. Dr. Manyak touched on the ground-breaking discovery of Penicillin, a feat that allowed physicians to effectively treat bacterial infections. She expressed that in the 15th and 16th centuries humans “believed that evil spirits were the roots of all diseases” a hindrance that was not overcome till “the scientific revolution and enlightenment.” Mrs. Ray discusses that changes such as “protective equipment,” “negative pressure rooms in hospitals” and readily available testing have become the normal now that, as a society, we actually understand the “transmission of the virus and bacteria” that cause epidemics. In comparison to the 16th century, Mrs Ray believes we now have extensive “knowledge and ability” to fund new research, discover unseen treatments, or find previous viruses that resemble COVID and instead of beginning at square one, have a base of information to refer to and build upon.

Thus, after interviewing these three medical professionals in very different aspects, we are able to compare aspects of COVID-19 to the Black Plague and other pandemics in the past. We gather that many trends are similar to those in the past, however use of virtual medicine and advancements in technology have made the progressions in COVID-19 different from those of the Black Plague. By interviewing these medical professionals, we can gain insight on the evolution of technology in medicine, which has impacted this pandemic in several ways.

Conclusion: Written by the entire team

Throughout this essay we examine the evolution of the medical response to plagues over time. While our medical knowledge is much more expansive now, we can examine the foundations for public health policies and medical treatments that started during the Black Death. Medical experts during that time had a severe lack of understanding of the human body, and no real concept of bacteria transmission. The treatments invented during the time period were unique to say the least, and mainly ineffective. However, many doctors began to implement ideas of quarantine and isolation. Making sure infected patients remain away from the rest, advising the usage of masks, and quarantining ships that arrived at ports for forty days after arrival are all public health policies still intact and used in current time, especially as we experience a pandemic of horrific size.

Between the Plague of Justinian and the Black Death, the major shift in thinking occurred in religious beliefs. During the first plague, there was limited knowledge of the causes of plague. This led to the majority of people unquestioningly believing that it was due to the wrath of God and that only religious practices could stop the spread of plague. During the Black Death, lack of response from God led people to lose faith in their religion. The causes of the Black Death were pinned on the Devil and on minority groups, such as the Jews. This marks the very beginning of public acceptance of scientific explanations for plague rather than religious explanations. Harshini's part:

Medical analysis of plagues have made significant advances since the first known plague. In the past, healers attributed the causes of plague to be a result of astronomical effects. Common people mostly thought that plague was God's punishment for human sin. Modern day medical

analysis finds that plagues are caused by earthly conditions, not abstract forces. These changes are the result in scientific advancements and a deeper understanding of the world.

In the next section of the paper we discover how medical analysis of transmissible diseases is in the modern day. We discovered there are five criteria to be considered: an infection agent, a reservoir, a mode of transmission, a route of entry, and a susceptible subject who becomes infected with the virus. After learning how transmissible these diseases are it was established that we must take the necessary precautions, both individually and publicly, to contain the spread of such diseases. The development of vaccines is the modern miracle for battling transmissible diseases, containing small amounts of the virus that is just enough to trigger the bodies' immune system to release antibodies. Antibiotics have also been developed, not to combat diseases but rather kill off bacteria during a bacterial infection. When looking into new treatments, antibacterial resistance poses an issue, as the increase in drug resistance makes medicines more ineffective over time. To combat this, new programs have begun to conduct research for new vaccines and medicines, with a systematic approach. While medicines are effective, it is crucial that one continues to maintain independent health by preventing illnesses in daily life through sanitization, careful food preparation, etc. In addition, the healthcare system recognizes trends in illnesses, to be able to identify these outbreaks as soon as possible. In the future, there are hopes for implications of more technological aspects to this prevention system. Going further off of that, global surveillance is of utmost importance, as it helps prevent the spread of diseases worldwide. We conclude this by exploring the fact that there is a gap between the life expectancy of the rich and the poor, as the supplies, sewage systems, safety, and vaccination access benefit the rich.

In our last section, we examine the aspects of medicine, in comparison with that of past plagues, by talking directly with medical professionals. Through interviews with Dr. Manyak, a pharmacist, Dr. Eric Tong, a kidney doctor, and Mrs. Olivia Ray who graduated from Wake Forest School of Medicine and is currently looking for a job in the field, we were able to collect very vital and direct information. One of the most significant ideas we picked up on that differentiates COVID-19 from past pandemics is the use of virtual technology. This switch from in-person to virtual has changed medicine, for the contact is much less prevalent. Advancements in technology have made the progression of COVID-19 much different from that of the Black Plague, as medical professionals are actively working to prioritize those with urgent needs, and those who don't need to visit the office itself, are able to stay safe in their homes. Our interviewees also touched on the question of the difficulty of finding a vaccine for COVID-19. Unlike the past pandemics and the plague, the entire world is counting on the active medical world to find a vaccine, test the vaccine for efficiency, and distribute it to everyone in need. Furthermore we received valuable insight with concern to the subjects of epidemiology regarding history. Dr. Tong, MD, Dr. Manyak Pharm. D., and Mrs. Ray MMS, PS-C gave us not only a broader perspective of the innovation and technological advances in medicine in relation to COVID-19, but also in relation to the Great Plagues of past times. Dr. Tong began by relaying that even with advancement, the discovery of a vaccine is complicated by immune responses such as Cytokine Storms and the rapid mutation of various virulent strains. Each of the medical professionals agreed that there has been a significant scientific revolution from the 1600's when Yersinia Pestis ravaged Europe. Mrs. Manyak touched upon the change in mindset that swept through the population, particularly how evil spirits were no longer deemed to be the root of all

worldly ailments. In further elaboration, she identified the creation of Penicillin to combat bacterial infection as a significant step for medicine. Our interviewees revealed just how astounding the rapid evolution of medicine is, and how the vast acquisition of newfound knowledge is in a state of constant progression.

Our Pioneer Open Summer Study team is primarily composed of juniors and two seniors. Often, we find ourselves juggling our time between attending rigorous courses, participating in extracurricular sports and organizations, as well as compiling research for projects such as this one. However, we utilized proper time management and meticulous planning to make sure there were minimal schedules clashes in our meeting times and individual research time; Practicing these methods, we were able to establish a successful plan and effective team work ethic. Each member contributed about 3-5 hours of their individual research each week. This was then read by each team member and at the end of our project compiled into a useful resource for reference. Overall, each member collaborated in creating a research paper housing an array of various explorations into the field of Epidemiology, and each one of us is grateful for not only the opportunity but the experience we gained from it as well.

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