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Pandemic Pandemonium: The Interconnectedness of Environmental and Public Health Through the Lens of COVID-19

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Abstract

In 2020, the world was launched into a global pandemic it was completely unprepared to fight. This pandemic began in the midst of tragic environmental disasters, including the largest wildfire recorded in California history. Once the global lockdown began, many long-standing environmental problems began to remedy themselves due to the sudden halt of human interaction. However, there were major environmental setbacks in the healthcare industry as increased medical waste and single-use items became a necessity. This thesis addresses how the pandemic impacted the environment through a lens of sustainability and public health, and how healthcare industries can be more prepared to fight another pandemic. Chapter 1 discusses the pandemic's positive ecological impacts due to quarantining and social distancing, such as the improvement of air quality and the reduction of noise pollution. It also discusses the negative consequences of COVID-19 on the environment, namely the proliferation of hazardous and pollutant medical waste and disposable masks. Chapter 2 delves into the past and present state of the healthcare industry's preparedness and sustainability in dealing with pandemics like COVID-19, and how it has changed in the COVID world. Chapter 3 discusses pandemic-related economic costs in the healthcare sector to the industry and citizens, and the waste-management difficulty exacerbated by excessive medical waste. Chapter 4 discusses public policies implemented throughout the pandemic, and how they impacted the environment and public health. Chapter 5 discusses what we learned from the COVID-19 pandemic and how we can create more sustainable practices in a healthcare setting while still preserving the abundance of caution necessary in the current state of medicine.

Keywords: public health, healthcare industry, COVID-19, waste, sustainability

Table of Contents

Introduction: Wear a Mask, Please

Chapter 1. The Pandemic's Impact on Public Health and Sustainability
a) Ecosystem Services
b) Causes and Effects
c) Future Discussions

Chapter 2. Past and Present Healthcare Strategies Against Pandemic Diseases
a) Advancements in Disease Prevention and Treatment
b) The Continuum of Public Health and Medical Care
c) Shortcomings of Modern Medicine
d) Modern Responses to Pandemics: H1N1 and Ebola Case Study

Chapter 3. The Pandemic's Economic Impacts in the Healthcare Sector
a) Public Health and the Global Economy
b) Waste Management
c) The Circular Economy

Chapter 4. Environmental Health and Public Policy
a) The Structure of Government Public Health Defenses
b) Environmental Impact of Policy During the Pandemic
c) Relaxation of Environmental Protection Policies
d) Case Study: Pandemic Fiscal Policy and Climate Change
e) Future Global Collaboration

Chapter 5. Future Avenues Towards Sustainability in Healthcare
a) Converting the Linear Economy to Circular
b) Improvement of Medical Waste Treatment Methods
c) Healthcare Education and Accessibility as Preparedness
d) Preventative Measures against Zoonotic Disease Transmission
e) Conclusion

Bibliography

Introduction: Wear a Mask, Please

As a high school senior in 2020, the global COVID pandemic was earth shattering to me. In the midst of my final months before graduation full of celebration and nostalgia, I never expected it to be cut so short. I had been working on the Spring Musical for several months and was ecstatic to share what we were working on with the world. When all in-person activities were halted the day before opening night, my heart was completely broken. Little did I know, this pandemic would not only cancel my senior musical and graduation, but would alter the culture and function of our society for several years as everyone's main priority became safety from COVID-19.

The COVID-19 pandemic caused a colossal shock at the most far-reaching global scale possible. It permeated every aspect of our lives and left an everlasting mark on every sector of society. Wearing a mask was no longer something only healthcare professionals knew the feeling of; it became a daily norm to wear a face covering as a necessary safety precaution, because the COVID-19 virus could be spread through the air. The media was plagued with uncertainty and panic, as new information on COVID-19 seemed to take ages to be released and fantastical speculations were dangerously rampant. Society learned how to operate solely with the trust of internet connection, as employees and students across the globe resorted to remote activity in an effort to avoid the virus spreading. Months and months of time spent solely at home meant that commutes were canceled, social gatherings and entertainment were few and far between, and green space was utilized more than ever to preserve mental health.

The pandemic began at a scary time for the climate, as forest fires and winter heat waves were cause for alarm among environmental activists. Miraculously, the sudden pause in societal movement actually had wonderful impacts on the environment, some of which still last today.

The lack of commuter traffic meant that noise pollution and air pollution were greatly reduced. This indirectly led to improvements in water quality, as rainwater was less contaminated. Additionally, reduced human activity led to the resurgence of wildlife in places where it normally would not be seen due to high human volumes[1], and animals traveled longer distances without the threat of human activities. Despite resulting only from a temporary change in human activity, wildlife vehicle collisions and wildlife mortality on highways also decreased in the 10 weeks following the global lockdown due to traffic reductions.[2]

However, COVID-19 also resulted in many environmental setbacks. The pandemic saw an increase in illegal deforestation, as most governments turned their attention to handling the pandemic and did not have the resources to handle this issue. Deforestation is a gateway to many other environmental problems, including global warming, changes in precipitation, and ironically- the transfer of zoonotic diseases to humans. Zoonotic diseases like COVID-19 are spread to humans via deforestation because this displaces reservoir species such as bats from their natural habitat, therefore making it much more likely that we come into contact with these species. We are also then susceptible to receiving the diseases that reservoir species carry but are not affected by; This is because humans have not yet been exposed to them in their evolutionary history. In addition, the pandemic created a reliance on disposable masks, which caused plastic waste and litter to accumulate in the environment. Biomedical waste was already poorly managed prior to the pandemic, and the severity and scale of COVID-19 greatly worsened this problem.

Overall, the pandemic brought about many changes in the environment that have strong implications on public health overall. It also created changes to the healthcare industry that

[1] Patlolla, Smith, and Tchounwou1 2022, 5-7.
[2] Shilling et al. 2021, 4.

negatively impact the environment. The interactions of these two factors with the pandemic, as well as their consequences on each other, constitute my thesis project. The pandemic was caused by increased interactions with exotic animals which is exacerbated by anthropogenic environmental changes such as deforestation. This created a global pandemic that the healthcare industry did not have the capacity to handle: biowaste could not be properly disposed of and single use unsustainable items such as disposable masks became a necessity. Chapter 1 will lay out the pandemic issue in greater detail, discussing its positive and negative impacts on healthcare and the environment. Chapters 2-4 will explore the historical approach to pandemics in healthcare, the economic impact of the pandemic on healthcare, and how zoonotic disease spread can be prevented from an environmental health and policy standpoint. Lastly, in Chapter 5, I will provide my own recommendations for how to improve the healthcare industry's carrying capacity without producing excessive amounts of non recyclable wastes.

Chapter 1. The Pandemic's Impact on Public Health and Sustainability

Chapter 1 will examine the COVID-19 pandemic's effect on public health, for better or for worse, in relation to the environment. It discusses how public health relates to ecosystem services, which are necessary for the well-being of all life on earth. In other words, I will explain why public health and the environment are inextricably linked. I discuss how the pandemic was not only caused by the degradation of the ecosystem services surrounding public health, but also furthered their deterioration, therefore creating a cyclical issue. By discussing the zoonotic origins of COVID-19, this chapter shows how fragile our interactions are with the environment and how this can have globally reaching impacts on public health. It also considers how COVID-19 altered both the healthcare sector and the human treatment of the environment, and

how these reciprocally impact each other both positively and negatively. Lastly, this chapter aims to begin the evaluation of this issue through historical, economic and environmental health/policy lenses. All of these disciplines will be extensively elaborated on in subsequent chapters.

Ecosystem Services. Ecosystem services are defined as any advantage that an ecosystem provides to a living organism, particularly humans. They are divided into 4 categories: provisioning, regulating, supporting, and cultural, as defined by the United Nations Millennium Ecosystem Assessment.[3] All four of these categories represent the ways in which people can benefit from the environment they live in through increased survival and improved quality of life. In the realm of healthcare, ecosystem services are extremely important, and our well being depends on our interactions with the environment.

The provisioning ecosystem services at work for public health are products derived from ecosystems, or the natural resources we take from the environment. The food we eat, the water we drink, and the medicines we consume are all provisioning ecosystem services that are essential for a healthy lifestyle. For example, soil is a significant ecosystem service that we do not typically think about from a health perspective, despite its great importance for the health of all humans. However, the homes we live in for protection and the produce we consume for nutrition are both indirectly contingent on the quality of our soil, as lumber-producing trees and global food crops must grow in proper soil in order to be extracted at high quality.[4] Without provisioning ecosystem services we would not be able to survive, which is the first and foremost goal behind being healthy.

[3] Millennium Ecosystem Assessment 2005, 40.
[4] Brevik et al. 2018, 87–92.

Regulating ecosystem services are those that provide health benefits that are acquired from the regulation of ecosystem functions. Essentially, they are necessary for healthy living rather than just survival. From a public health standpoint, this includes air quality, which is necessary for healthy lungs and is worsened by pollution from cars and diesel trucks. This can also include disease regulation, as alterations to the environment can have direct impacts on the population of disease vectors and abundance of disease-causing agents. This is particularly relevant to COVID-19, as it is a zoonotic disease which was likely transmitted because of changes in how humans come into contact with the environment.

Supporting ecosystem services are strongly connected to the previous two, as they are fundamental for underlying natural processes. For example, if air quality (a regulating service) is compromised, then this pollution may enter the water (a provisioning service), by way of the water cycle (a supporting service). Both air quality and water quality are essential ecosystem services for public health, as previously explained, and they are interconnected through supporting services. The water cycle is therefore indirectly linked to public health through other services. Another supporting service would be the provisioning of habitat- this is especially relevant to public health because of zoonotic disease transfer being linked to habitat destruction. Excessive deforestation can result in increased contact with vector species carrying infectious diseases, thus increasing the chances of zoonotic disease spillover in humans.[5] Therefore, habitat preservation is extremely important for protecting humans from exposure to pathogens they are unprepared to fight off.

Lastly, cultural ecosystem services are benefits obtained in nonmaterial ways, such as being in the presence of nature in general. In other words, they are acquired through mental enrichment, sensory experiences, social connections, or other non-physical means. In terms of

[5] Eby et al. 2022, 340.

public health, being outdoors and exercising provides great benefits for mental and physical well-being.[6] Utilizing green spaces is beneficial for stress relief, increased sense of community, recreation, and a sense of connectedness with nature; all of these perks come with proven health benefits, including (but not limited to) improved cognitive functioning, happiness, and hearth strength.[7] Overall, ecology and one's health are inseparable subjects, as proven by the many health benefits gained from the ecosystem.

Causes and Effects. So where does COVID-19 tie in? Because of the pandemic, the healthcare industry and its ecosystem services became severely disrupted. Before we dive into how this happened, it is necessary to establish COVID-19's origins. COVID-19 is a highly infectious and pathogenic disease caused by the severe acute respiratory syndrome coronavirus 2, or SARS-CoV-2, and there have been five mutated strains since the beginning of the pandemic.[8] COVID-19 is a zoonotic disease, or one transferred from animals to humans, and there is great uncertainty regarding the timing and mechanism of its transfer. Zoonotic diseases can be transmitted through various means, including direct contact with an infected animal, consumption of contaminated food or water, or exposure to vector organisms, such as mosquitoes or ticks, that carry the disease. Although the exact cause or root of this transfer is unconfirmed, many reports cite that the virus was transferred at a seafood market in Wuhan, China in November, 2019.[9] Previous studies have posited that it is unlikely for COVID-19 to have been transmitted directly from bats to humans without the presence of an intermediate reservoir species.[10] The virus likely originated in bats and was passed through another reservoir

[6] Schneider et al. 2021, 1.
[7] Chen et al. 2019, 2122.
[8] Hao et al. 2022, 1.
[9] Arora and Mishra 2020, 117.
[10] Hao et al. 2022, 6.

species to humans, which is not surprising as 70% of the world's emerging viruses are zoonotic in nature.[11]

As previously discussed, zoonotic disease spillover is often caused by habitat destruction which creates unstable conditions for organisms in surrounding lands and forces them to relocate to other areas. These areas can very likely be located near human inhabited spaces, thus making the likelihood of disease transfer higher.[12] Therefore, a cause of the pandemic was the improper handling of ecosystem services, namely the supporting ecosystem service of habitat provisioning.

Zoonotic diseases afflicting human beings is nothing new. It is unknown when these diseases first emerged, but it is likely that the domestication of livestock and the concentration of human populations into dense communities thousands of years ago are origins of causation.[13] Any large-scale anthropogenic environmental modification leads to an increased likelihood that zoonoses will emerge, as alterations to the environment can increase human interactions with animal species carrying these diseases. In fact, it is estimated that at least 50% of zoonotic disease emergence since 1940 is actually associated with agriculture. Food systems require the clearing of forests and other natural habitats to create farm lands (as well as the concentration of animals and their waste), which therefore increases exposure of nearby human communities to wildlife and heightens their risk of contracting zoonoses.[14] Globalization in general contributed to the unmanageable state of COVID-19, as the world is so greatly connected and disease can easily spread. This is another reason why zoonoses are contracted in the first place: the

[11] Ibid.
[12] Eby et al. 2022, 340.
[13] Daszak 2012, 1883.
[14] Hayek 2022, 1.

development of global trade and travel has altered the environment and created novel interactions between humans and animals that are bound to lead to zoonotic disease transmission.

With over 1 billion international travelers in just 2019 alone[15], it is no wonder how quickly COVID-19 spread into a global pandemic. According to the World Health Organization (WHO), there have been 775,335,916 confirmed cases of COVID-19 globally and 7,045,569 deaths since April 2024, which shows the tragic toll that this virus has taken on people around the world.[16] The scale of the COVID pandemic makes it one of the deadliest in history, and the colossal impacts of COVID-19 in every sector of society do not stop there. The economy took huge hits during the pandemic, as many people were laid off and lived on stimulus checks to feed their families without an income. Unemployment rates peaked at 14.8% in April 2020 and plateaued to 6.2%, remaining greatly elevated since the previous year. These rates were highest in industries providing services that must be in person, with the leisure and hospitality industry having an unemployment rate of 39.3% in April 2020.[17] Additionally, the International Monetary Fund (IMF) estimated that the global economy contracted by 3.5% in 2020.[18] As illustrated by these statistics, the COVID pandemic had widespread negative effects on society, and strategies to mitigate these effects spiraled into many environmental consequences that will be thoroughly explored in this thesis.

The pandemic had a wide range of impacts on the ecosystem, many with positive public health outcomes. For example, once lockdown began, major improvements were made in air quality of cities across the world. In China, there was a 25% decrease in emissions from when the lockdown started until April of 2020, and many polluted cities showed visible reductions in

[15] Herre, Samborska, and Roser 2023.
[16] "Who Coronavirus (COVID-19) Dashboard." World Health Organization.
[17] Falk et al. 2021.
[18] International Monetary Fund, 2021.

smog.[19] Additionally, PM2.5, a dangerous fine particulate matter that harms human respiratory health, saw statistically significant global decreases due to lockdown, as well as a 25.5% decrease in NO_2 concentration in the air compared to historical years.[20] In some small cases, water sources saw a decrease in nitrogen concentration as a result of the lower nitrogen emissions.[21] The implications of air quality improvements are intuitively connected to the overall health of society, especially in areas like the Bronx where air quality has been known to cause increased rates of asthma. Lockdown also resulted in a reduction of noise pollution, as loud activities such as drilling, mining, manufacturing, and even heavy city traffic were no longer completed; this has positive impacts on the wellbeing of humans, as noise disturbs one's psycho-social state.[22] Remote societal conditions meant that outdoor recreation was especially important to preserve mental wellbeing. Green spaces were of great benefit to mental health and they became more important than ever in urban settings. Many cities saw increases in their use, including Oslo, Norway where outdoor recreational activity saw a 291% increase.[23]

The lockdown period during the pandemic resulted in temporary improvements for wildlife as well. Normal traffic patterns were altered, as commutes were canceled due to remote work and people remained at home to practice social distancing. Reduction in traffic volume had positive impacts on wildlife, resulting in decreased roadside wildlife mortality and wildlife-vehicle collisions; for example, California saw a 58% reduction in mortality of mountain lions in the 10 weeks following the lockdown.[24] Other research conducted by an international research team revealed that wildlife traveled greater distances during lockdowns, highlighting the

[19] Saadat, Rawtani, and Mustansar Hussain 2020, 4.
[20] Berman and Ebisu 2020, 2.
[21] Zhang et al. 2024, 5.
[22] Patlolla et al. 2022, 9-19.
[23] Schneider et al. 2021, 1.
[24] Shilling et al. 2021, 1.

sensitive dynamic between animals and anthropogenic activity.[25] Additionally, dolphins were sited in several locations for the first time in a decade, including the Venice Canals and the Coast of Bay in Bangladesh.[26] The reduced human activity during the lockdowns allowed for some ecosystems to experience a respite from the pressures of human encroachment. With fewer disturbances from human presence, wildlife habitats may have had the chance to recover and thrive in unexpected ways. However, it is essential to recognize that these positive changes were temporary and contingent upon the unique circumstances of the pandemic. While societies transition back to in-person procedures and activities resume their usual pace, it will be crucial to consider how to sustainably balance human needs with the conservation of wildlife and their habitats.

Of much greater concern are the negative impacts that pandemic-related changes in the public health sector have had on the environment. Prior to the pandemic, medical waste disposal was already difficult to manage. It is considered the second most hazardous waste in the world, behind radiation, and was already poorly managed prior to the pandemic's beginning.[27] The pandemic greatly exacerbated the production of medical waste, due to the surge of patient numbers and the necessity for single-use items that would curb the spread of COVID-19 on surfaces. Additionally, the World Health Organization (WHO) made recommendations for increased use of personal protective equipment (PPE), including masks and gloves to dampen transmission of COVID-19. Government-mandated and health-professional endorsed mask usage meant an astronomical increase in pollution due to the necessity of disposable masks. It is estimated that 1.24 trillion single-use face masks wound up in the environment during the

[25] Corradini et al. 2021.
[26] Rume and Islam 2020, 5.
[27] Tushar et al. 2023.

pandemic's main 18-month time period from December 2019 to May 2021.[28] Even though many masks were made to be reusable, these regular cloth coverings were often not as trusted because they lack specialized filtration that other single-use medical-grade masks have. Reusable cloths also lose effectiveness after multiple washes and they have less fabric layers which reduces their filtration ability.[29]

Many studies have been conducted to investigate the exact impact of these masks on the environment, all of which claim the transfer of microplastics into the environment is the biggest concern. One study which measured the microplastics in soils with and without face masks found that there was an average of 3820.45 microplastics per face mask in the soil after just 40 weeks.[30] Facemasks are lightweight, meaning they have low air resistance and disperse very easily into the environment.[31] Therefore, the dispersal of these masks means greater accumulation of microplastics in the environment, which are very harmful for ecosystems and their organisms. Particles from facemasks can be unintentionally ingested by small invertebrates, leading to a false sense of satiety and eventually cause death by starvation.[32] This can lead to biomagnification through trophic levels, meaning that microplastics could end up in our food supply, creating implications for human health as well.

The proliferation of facemask usage amidst the COVID-19 pandemic has also posed significant threats to marine life. In the United States, disposal of PPE resulted in a 70% increase in marine litter, which can harm marine organisms and damage the ocean's ecology.[33] Additionally, during the initial phase of the pandemic in 2020, 1.56 billion facemasks were

[28] Idowu, Oluwasogo Olalemi and Festus Aiyesanmi 2022, 2.
[29] Oliveira et al. 2023, 2.
[30] Idowu, Oluwasogo Olalemi and Festus Aiyesanmi 2022, 2.
[31] Oliveira et al. 2023, 3.
[32] Ibid., 9.
[33] Rai et al. 2023, 4.

disposed of in marine environments.[34] Although not many studies have been conducted on the degradation of facemasks in aquatic environments, polypropylene-based materials are unlikely to degrade and could take up to 450 years to do so, or longer without abiotic degradation of the hydrophobic mask surface.[35] Facemasks pose great harm to marine and terrestrial wildlife even before their degradation, as they have been known to cause entanglement and asphyxia and be ingested.[36] The improper management of excessive PPE waste during the pandemic will be further discussed in Chapter 3.

Face masks were not the only major pollutants: people purchased and used more disinfectants in an effort to keep surfaces and hands clean. These are often packaged with macroplastics and are made with triclosan, an antibacterial compound found in hand soaps. Diclofenac is another environmental pollutant that is present in painkillers. All of these pollutants were found to accumulate in the world's rivers as a result of COVID-19 measures, with macroplastics increasing 56%, triclosan increasing 33%, and diclofenac increasing 50%. This is harmful to all species using these water sources, including humans.[37] The healthcare industry was extremely unprepared for this pandemic, as the only foreseeable solution at the time was the mass production of disposable masks and other PPE. The world was forced to manage the crisis in a manner that was known to harm the environment, because slowing the spread of the disease was the only way the healthcare industry would be relieved from working over their capacity.

Future Discussions. Later on, this thesis will discuss further how the pandemic interacted with public health and the environment through other academic disciplines. Taking a closer look

[34] Rai et al. 2023, 5.
[35] Oliveira et al. 2023, 8.
[36] Ibid., 9.
[37] Zhang et al. 2024, 2-5.

at the healthcare industry's response to past and present disease crises, it is apparent that there is a need not only for greater preparedness in public health crises, but also preventative measures for zoonotic disease transfer. Research discoveries and inventions in the field of healthcare have come a very long way, but there is still a necessity for organized emergency protocol and greater efficiencies regarding hospital infrastructure. From an economic perspective, the healthcare industry was spread extremely thin by COVID-19, and there is a scarcity of resources to handle this crisis at a large-scale level. PPE must be constantly replaced to prevent the virus's spread and contamination, yet at the same time its production is having catastrophic effects on the health of the environment.

Policymakers must find a way to reduce the necessity for PPE while still meeting the demand for it in healthcare. Perhaps more importantly, there should be open collaboration between the scientific and health communities along with policymakers in order to prevent the transfer of zoonotic diseases to humans in the first place. There also must be efforts made to find sustainable ways to contain zoonoses and other novel diseases once contracted. This would prevent environmental catastrophe in a future pandemic. Chapter 5 will explore avenues toward solving these problems in greater depth.

Chapter 2. Past and Present Healthcare Strategies Against Pandemic Diseases

Humans have had a long and difficult relationship with pandemic diseases. The earliest known pandemics did not exist alongside modern healthcare, but strategies created since such as the use of antibiotics, vaccinations, hygienic practices, and social distancing measures could have prevented them from reaching the severity that they did. On the flipside, many recent pandemics are the result of zoonotic disease spillover due to habitat loss, and they would not

have been as likely to occur centuries ago than in our globalized society. Pandemics have become more common because of anthropogenic environmental change, and modern healthcare strategies inevitably fall short in combating the influx of new diseases arising from it, as well as containing extremely large populations of exposed people. Chapter 2 evaluates the rise of modern healthcare, its development in the United States, and its successes and shortcomings in strategizing against previous health crises. It specifically discusses fundamental problems in healthcare that lead to an unpreparedness in emergencies such as COVID-19. It also zooms in on how past zoonotic disease spillover events were handled in comparison, using the H1N1 and Ebola viruses as a case study.

Advancements in Disease Prevention and Treatment. It is important to recognize how our knowledge of disease and health has evolved in just the last few hundred years. One of the earliest well documented pandemics, the Black Death, claimed over 25 million lives in Europe from 1346 to 1353, and was transferred to humans through animals and their fleas. People did not understand how this disease spread and there was no ubiquitous strategy to manage the pandemic, but there were preliminary practices of wearing face masks, implementing quarantines for arriving sailors, and creating mass graves to contain sick bodies.[38] This pandemic was also spread by the expansion of trade routes throughout Europe and other continents, as globalization is a huge contributor to the uncontrolled spread of zoonotic diseases.[39] The next great pandemic was smallpox, which wiped out indigenous populations that had zero natural immunity to the disease. However, the smallpox pandemic led to one of the most important discoveries in medicine- the vaccine. Edward Jenner, a scientist who discovered how milkmaids who caught cowpox from their cows also acquired smallpox immunity. He confirmed this observation by

[38] The Black Death 2017.
[39] Daszak 2012, 1883.

exposing a test subject to cowpox, and after variolating him with smallpox, he found the subject was immune.[40] Since then, vaccines have grown much more organized and scientifically advanced, with over 30 vaccine-preventable diseases to date. Vaccines have proven vital to the control of modern epidemics, especially COVID-19.

In the late 1800s, there became increasing concerns about public sanitation, as there were numerous assertions presenting scientific evidence linking the spread of infectious disease with poor ventilation and damp, unclean conditions.[41] The germ theory of disease began to gain widespread popularity in the 1880s, and a sense of public responsibility for slowing the transmission of disease was gaining traction. The germ theory hypothesizes that diseases are caused by microorganisms, and these particles were readily associated with uncleanliness, garbage, sewers, and dirty air.[42] This theory prompted improvements in plumbing, increased accessibility of water filtration, and encouraged antiseptic practices in the home as people wanted to avoid contracting disease or infection.[43]

Another significant advance in medicine was the discovery of antibiotics. The first antibiotic available for public use was penicillin, discovered by Alexander Fleming in 1928 and later distributed on a large scale throughout the Second World War.[44] Fleming's accidental discovery of penicillin's antibacterial properties marked the beginning of a new era in medicine. Since then, numerous antibiotics have been developed to treat a wide range of bacterial infections, from common illnesses like strep throat and urinary tract infections to more serious diseases like pneumonia. Antibiotics work by either killing bacteria or inhibiting their growth, providing effective treatment options for bacterial infections. The widespread use of antibiotics

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[40] Riedel 2005, 21-25.
[41] Tomes 1990, 510-513.
[42] Ibid., 528-529.
[43] Ibid., 509.
[44] Riedel 2005, 21-25.

has saved countless lives and revolutionized the treatment of infectious diseases. However, overuse and misuse of antibiotics have led to the emergence of antibiotic-resistant bacteria, posing a significant threat to public health. Despite this challenge, antibiotics remain indispensable tools in modern medicine, continuing to play a crucial role in treating infections and improving patient outcomes. The germ theory helped modern medicine discover the origin and spread of disease, and vaccines and antibiotics are extremely important to the treatment and eradication of modern pandemics.

The Continuum of Public Health and Medical Care. Within the healthcare system, there is a distinction between the roles and objectives of public health and medical care. Although both are crucial for the health and well-being of individuals and communities, public health works at the macro-level, governed by established public health agencies for the protection of the population as a whole, while medical care works on the treatment of individual patient needs. Historically, these domains have been separated in the United States, with public health and sanitation being a responsibility of states and localities, and medical care residing in the private sector.[45] In the 1800s, when advancements in microbiology suggested that people could spread infectious diseases, this brought both fields in close contact with one another as the public sector could conduct initiatives to prevent disease and relieve the medical care domain. Throughout the 1900s, the federal government's role in public health expanded to provide support through funding disease-specific initiatives, offering policy guidance to local public health organizations, and establishing agencies like the Department of Health and Human Services (HHS), the Centers for Disease Control and Prevention (CDC), and the Food and Drug Administration (FDA).[46]

[45] Bourdeaux et al. 2023, 311.
[46] Ibid., 311.

While the United States boasts achievements in biomedical research, advanced medical technology, and specialized healthcare facilities, significant challenges persist in ensuring access to the healthcare system and delivering quality care to all Americans.[47] The United States remains behind other high income countries in terms of healthcare coverage. Despite healthcare spending being far higher, the United States exhibits the lowest life expectancy at birth, the highest mortality rates for conditions that are deemed preventable or manageable, the highest rates of maternal and infant mortality, yet is still the only country lacking universal healthcare.[48] Access to healthcare services, particularly in rural and disadvantaged urban areas, remains limited, exacerbated by a shortage of primary care physicians and an overreliance on emergency departments for a range of healthcare needs, including acute, chronic, and preventative care.[49] Attempts to make healthcare coverage universally accessible in the United States have persisted since the presidency of Theodore Roosevelt, and yet the closest forms of publicly available medical insurance are Medicare and Medicaid.[50] Despite having complementary goals, public health and medical care sectors often encounter inefficiencies and coordination problems that countries with centralized healthcare systems do not run into.[51] The disconnect became glaringly apparent during the COVID-19 pandemic, as the United States floundered in its emergency response while other countries excelled. This will be explored more in depth in Chapter 5, where benefits of Universal Healthcare during the COVID-19 pandemic are debated and discussed at length.

Shortcomings of Modern Medicine. In order to understand how unprepared we were for the COVID-19 pandemic, it is important to discuss how overwhelmed the healthcare system had

[47] Woolf and Aron 2013, 106.
[48] Gunja, Gumas, and Williams II 2023.
[49] Woolf and Aron 2013, 106.
[50] Griffin 2020.
[51] Bourdeaux et al. 2023, 310.

already become. Far prior to the pandemic's onset, there was far-reaching concern of a physician shortage facing America. In 2017, the Association of American Medical Colleges predicted a shortage of 40,800 to 104,900 physicians by the year 2030.[52] This is an extremely concerning statistic considering the rate at which new diseases emerge. However, it has been claimed that this problem will not be solved by adding new physicians, and can only be solved by reforming the inefficiencies within the system itself. Additionally, as discussed in Chapter 1, we need to not only reform our healthcare system to accommodate for constantly evolving pathogens, but also address what human-induced environmental changes are making diseases reach humans in the first place. Tackling the root causes of environmental degradation and its impact on human health is imperative for long-term disease prevention and management. This will be discussed in more depth in Chapter 5.

It is clear that we are not using our physician population efficiently, whether that be due to inflexible hours, uneven distribution of physicians, or simply the extreme cost of healthcare today. Another way that healthcare is overwhelmed is in the domain of medical waste. Bio-Medical waste includes any waste generated at health care facilities during medical procedures, and has been increasingly generated as healthcare becomes more advanced and far reaching.[53] Medical wastes are dangerous due to their high potential to possess pathogens and their emission of hazardous gasses, which greatly pollutes the environment and can cause additional health complications.[54] Concerns about the health risks posed by medical waste came about in the 1980s following incidents of medical waste washing up on various east coast beaches; in response, Congress passed the Medical Waste Tracking Act (MWTA) in 1988, which

[52] Mann 2017.
[53] Goswami et al. 2021, 2.
[54] Babanyara et al. 2013, 758.

mandated the EPA to establish regulations for managing medical waste before its expiration in 1991.[55]

There is strong evidence that medical waste causes great harm to human health in several ways. In many parts of the world, it is common for waste handlers to manually scavenge and sort medical waste. This is an extremely perilous job, as needle-stick injuries, poisoning through waste water and toxic elements, and radiation burns are all potential injuries that can occur performing this task. Additionally, about 5.2 million people worldwide die each year from waste related disease, including 4 million children.[56] It is not surprising that medical waste is so dangerous when one considers its contents. Even though medical waste is most pathogenic at the point of generation and then decreases afterwards, there is still evidence of pathogenic species surviving for long periods of time on medical waste. (RT)-PCR assays performed on various medical waste sources have identified several species of opportunistic pathogenic bacteria and viruses, including *Pseudomonas* spp. and hepatitis B virus.[57]

Improper disposal of medical waste has been very common before, during and after the pandemic. Incineration is the most accepted method in the United States, and more than 90 percent of medical waste was incinerated prior to 1997.[58] The EPA required the installation of air pollution control devices in 1997 which resulted in the closure of over 5000 medical waste incinerators that could not afford the cost.[59] Unfortunately, there have been no environmentally safe and inexpensive options invented with medical waste disposal, although autoclaving is being looked into as a more sustainable method. After undergoing autoclave treatment, medical waste can be treated as municipal solid waste and disposed of with other non-infectious waste.

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[55] EPA 2024.
[56] Ibid., 758.
[57] Ibid., 760.
[58] EPA 2024.
[59] Windfeld and Brooks 2015, 101.

This is considered more sustainable because it does not release mercury or dioxin emissions, but it does not reduce the volume of waste entering a landfill, whereas incineration only leaves 20-30 percent of original volume of waste behind.[60] The problem is also exacerbated by the fact that 70-80% of infectious waste is actually noninfectious waste that once exposed must be disposed of as infectious[61]- this is a major inefficiency in the healthcare industry that greatly exacerbates the issue of medical waste disposal. Medical waste will be discussed in further detail in Chapter 3, as it is also an economic consequence.

Modern Responses to Pandemics: H1N1 and Ebola Case Study. As was discussed in the first section of this chapter, modern pandemics can be handled through collaboration with medical professionals and public health figures to find their origins and stop their spread. Many countries began developing emergency protocols incase of a pandemic throughout the 21st century. The 9/11 attacks and anthrax bioterrorism attacks in 2001 were main catalysts in this process, as they sparked paranoia and desire for emergency preparedness to feel a greater sense of domestic security.[62] In 2004, the World Health Organization (WHO) recommended all countries to develop preparedness plans in case of a pandemic, and a full collective doctrine was shared between powerhouse health agencies and international organizations worldwide. The consistent appearance of several infectious diseases, including Ebola, Zika SARS, and influenza (H1N1) were also triggers in connecting health authorities nationally and globally against the threat of a pandemic.

H1N1, also known as avian flu or swine flu, had a major epidemic outbreak from 2009-2010. This sparked very strong responses from governments and health agencies. However, the emergency protocol was later critiqued as too strong and unnecessarily alarming because

[60] Ibid., 105.
[61] Ibid., 106.
[62] Bourrier and Deml 2022, 2.

H1N1 turned out to be less virulent and lethal than originally feared.[63] Ironically, the emergency response of the COVID-19 pandemic was not nearly swift enough. The United States government's emergency response to the H1N1 epidemic was completed in its entirety after 28 days, whereas the emergency response to COVID-19 was completed in 46 days, making the H1N1 response 18 days faster.[64] What is more ironic is that the Global Security Index in 2019 ranked the United States in the top two most prepared countries in the event of a pandemic.[65] In reality, the United States had among the worst statistics for COVID-19 cases in the world. Reflections of the H1N1 epidemic can shed insight onto the early days of the COVID-19 protocol, as it was likely influential in early policies. The role of the United States Government and policy in the pandemic will be further discussed in Chapter 4.

The COVID-19 pandemic required immediate isolation and quarantine measures; given the unprecedented nature of the pandemic, researchers and healthcare professionals needed time to understand the science behind the virus, and the population was vulnerable for an extended time. There was also widespread distribution of PPE, telehealth medicine appointments, sanitation advertisements, and travel bans. This was quite different from previous pandemics, not just because of the approach, but because of the global scale these responses took place at. PPE had never been necessary to distribute to every single individual in the global population, which created tons more waste and a much greater impact on the environment than past pandemics. This will be further discussed in Chapter 3, which explains how our global economy has exacerbated the problem of zoonotic diseases and made them a much worse situation for people worldwide. Regardless, previous pandemics provide interesting insight into why COVID-19 was so devastating and what more could have been done to stop it.

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[63] Ibid., 4.
[64] Wang et al. 2020, 8.
[65] Ibid., 8.

From 2013–2016, the zoonotic Ebola outbreak emerged in middle Africa and then spread to other countries in Western Africa, resulting in 28,652 human infections and 11,325 deaths.[66] Part of the management for Ebola medical waste was instituting color-coded separation of different types of medical wastes, and this practice definitely increased safety for those handling and disposing of it.[67] Although most of the infected population remained in Africa, there were devastating outcomes for the populations of West Africa specifically, likely because of the disadvantaged position of the afflicted countries. More than 300 healthcare providers and nurses died because of the lack of control measures in West Africa, and there was a long period of time where global response to this tragedy was virtually nonexistent.[68] In the United States, there were more resources available to prevent the spread of Ebola early on, and there have been only a handful of US cases since the virus's discovery. The Ebola virus was mostly contained through PPE and isolation of patients through quarantines.[69] Travelers to the United States that were from countries with Ebola also had to be tracked to one of 5 airports in the United States to ensure the safe monitoring of the disease's spread. Overall, the Ebola pandemic was far more contained than COVID-19. This could be attributed to the containment strategies implemented and differences in the viruses themselves. COVID-19 can be carried for up to two weeks without presenting symptoms, making it extra difficult to trace. COVID-19 also had much farther reaching implications, possibly because it wasn't taken seriously by policymakers. As will be discussed in Chapter 4, collaboration between medical professionals and policymakers is crucial to the management of a global pandemic, and earlier restrictions will prevent hospitals from reaching their carrying capacity.

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[66] Centers for Disease Control and Prevention 2019.
[67] Mandoh et al. 2017.
[68] Ibid.
[69] Chung et al. 2021.

Overall, the Ebola pandemic was far more contained than COVID-19. This could be attributed to the containment strategies implemented and differences in the viruses themselves. COVID-19 can be carried for up to two weeks without presenting symptoms, making it extra difficult to track its spread and find the extent of an outbreak. As will be discussed in Chapter 4, collaboration between medical professionals and policymakers is crucial to the management of a global pandemic, and earlier restrictions will prevent hospitals from reaching their carrying capacity.

Chapter 3. The Pandemic's Economic Impacts in the Healthcare Sector

In the wake of the COVID-19 pandemic, the intersection of economics, healthcare, and sustainability is an extremely useful topic that provides insights into the pandemic's negative environmental impacts. Chapter 3 delves into the intricacies of healthcare economics, the pressing need for sustainable healthcare practices, and the exacerbation of medical waste challenges amid the pandemic. The healthcare system was pushed beyond its carrying capacity during the pandemic, and both healthcare workers and resources were scarce. Although the global economic shutdown saw temporary improvements in carbon emissions[70], the accumulation of medical waste created bigger problems and represents the shortcomings of a linear economy. As economies grapple with the disposal of escalating volumes of medical waste, the discourse shifts from conventional linear models to more sustainable circular approaches. The pandemic has magnified the urgency of addressing healthcare waste management, prompting a reevaluation of resource utilization and waste disposal strategies. Furthermore, this chapter explores the connection between global consumerism and the pandemic, illuminating how interconnected economies, driven by consumer behaviors, played a role in the spread and

[70] Khalaf et al. 2023, 6.

impact of COVID-19. Understanding these interwoven dynamics is essential for creating resilient, sustainable, and equitable economic frameworks that can withstand the challenges of both public health crises and environmental concerns.

Public Health and the Global Economy. Public health and economics are highly interconnected: a population's health status influences its economic productivity, while economic conditions shape an individuals' access to healthcare and health-promoting resources. A healthy population will be more efficient, and many sources have found that increasing public health expenditures will boost economic performance.[71] For example, Investments in public health infrastructure, such as emergency response systems or vaccination campaigns, will increase economic resilience by averting healthcare costs and productivity losses associated with illness. Similarly, socioeconomic disparities, driven by economic factors like income inequality and access to education and employment opportunities, significantly impact health outcomes. In the case of COVID-19, studies from various countries including the United States confirmed that people of low socioeconomic status were more vulnerable to COVID-19.[72] Overall, economic policies and decisions can profoundly affect public health of a population, either positively or negatively. This is especially true of environmental economic policies since environmental changes have direct effects on public health, as outlined in Chapter 1.

In considering the economics of the healthcare system, one fundamental aspect revolves around the structure of healthcare financing, often categorized as single-payer versus multi-payer systems. In a single-payer system, such as those found in some European countries like the United Kingdom and Canada, the government is the sole entity responsible for financing healthcare services through taxes. This model aims for universal healthcare coverage which

[71] Huang 2022, 9.
[72] Maher et al. 2022, 2.

reduces administrative costs and ensures equitable access to care. Conversely, in multi-payer systems like that of the United States, various private insurance companies, as well as government programs like Medicare and Medicaid, fund healthcare services. While this model offers more choices for consumers and fosters competition, it often leads to disparities in coverage and higher administrative costs.

As discussed in Chapter 2, COVID-19 spread faster than any previous pandemic due to the nature of our global society. While it took one year for the Spanish Flu to become a global pandemic, it only took COVID-19 three months.[73] The globalization of the economy played a pivotal role in the rapid spread of the COVID-19 pandemic. Economic growth exacerbated the spread of zoonotic diseases through excessive habitat destruction for the purpose of acquiring natural resources. The economy also contributed to the global traffic of humans, goods, and services across borders. The interconnectedness of the global economy, driven by factors like tourism and economic exchanges, facilitated the virus's transmission and drastically shortened the time it took for the pandemic to reach a global scale compared to historical precedents.[74] The COVID pandemic has unmasked many fragilities and vulnerabilities associated with the global economy.[75] The transmission of the virus also highlights socioeconomic disparities, as it was at first dubbed a disease of affluence for its association with travel and trade.[76] Overall, the pandemic was born out of our society's incessant obsession with economic growth and globalization.

The pandemic's profound economic repercussions on the healthcare system manifested in a variety of ways, with scarcity emerging as a glaring issue. This is exemplified by the extreme

[73] Jeanne et al. 2023, 1181.
[74] Ibid., 1181.
[75] Madhok 2021, 200.
[76] van de Pas 2020.

shortages of crucial resources, which were caused by overwhelming demand that far surpassed the capacity of hospitals and healthcare facilities worldwide. For instance, in China, the surge in demand for N95 respirators skyrocketed from 200,000 to an astonishing 1.6 million units[77], underscoring the unprecedented strain on medical supply chains. Shockingly, a survey conducted by the CDC's National Healthcare Safety Network during the early stages of the pandemic revealed alarming statistics: one-third of hospitals grappled with shortages of healthcare professionals, while 11 percent faced deficits in PPE and ventilator supplies[78], further exposing the systemic vulnerabilities within healthcare infrastructure. One study estimated that 24-hour intensive care treatment of a COVID-19 patient would need 36 pairs of gloves, 14 gowns, 3 pairs of goggles, and 13 face coverings, which is an overwhelming amount when considering that many hospitals had over 100% of their beds being used to treat COVID-19.[79] Overall, there are severe environmental consequences associated with the exponentially elevated production of medical supplies due to the demand of the pandemic, including increased carbon emissions and the generation of waste that will be discussed later in the chapter.

Moreover, scarcity causes disproportionate impacts on those of lower socioeconomic status or part of marginalized communities. Some factors that increase the impact of COVID-19 in lower socioeconomic groups include larger household size, which increases likelihood of bringing the virus home, job type, as those with higher paying jobs typically have the privilege of working from home, and access to healthcare services, as many people cannot afford health insurance, specifically in the United States.[80] Data on vaccine distribution within the United States revealed concerning disparities, with certain geographic regions experiencing markedly

[77] Cubas et al. 2023, 6.
[78] Wu et al. 2021, 2.
[79] Khot 2020.
[80] Saadat, Rawtani, and Mustansar Hussain 2020, 3.

lower vaccine coverage due to systemic barriers to healthcare access.[81] This further highlights the glaring inadequacies in ensuring equitable protection across populations, as scarcity of medical supplies means that the first people to be affected are those with less resources for their acquisition.

Waste Management. Waste management is a crucial function of an economy, and it is the essence of the healthcare industry's negative economic impacts on the environment. As discussed in Chapter 1, the pandemic created a huge demand for PPE, as this was one of the few ways the spread of the COVID-19 virus could be slowed. There was also a much greater volume of patients being hospitalized with COVID-19, leaving many hospitals with no room to spare. This created excessive amounts of medical waste and municipal solid waste that the healthcare system did not have the carrying capacity to dispose of. Hubei China saw a 370% increase in medical waste, predominantly of plastic material.[82] Medical waste in Wuhan increased from 40 to 50 tons per day to 247 tons per day by March 2020 alone.[83] In Bangladesh, COVID-19-related medical waste from patients increased from 658.08 tons in March 2020 to 16,164.74 tons in April 2021.[84] Even in households, single-use plastic items were generally regarded as safer for public health because of their disposability, despite being proven to have no difference from other materials in terms of virus retention.[85] This rapid augmentation of waste overwhelms waste treatment centers that are only equipped to handle a steady state of waste volume,[86] which provides insight into our inability to handle large-scale public health emergencies like COVID-19.

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[81] Cuadros et al. 2023, 2.
[82] Klemes et al. 2020, 2.
[83] Tushar et al. 2023, 1.
[84] Ibid., 3.
[85] Doremalen et al. 2020.
[86] Klemes et al. 2020, 1.

The sheer volume of waste produced due to hospital overcapacities and the demand for PPE was the straw that broke the camel's back. We did not have a sustainable or organized enough system in place to handle such an emergency. Healthcare facilities and households have always used medical supplies that are predominantly single-use items for sanitation or quality purposes. As aforementioned, disposable items are regarded as safer for health by the general public**.** Additionally, medical grade masks such as surgical masks and N95 masks are not supposed to be re-worn because their filtration effectiveness wears off after several hours, their fit is worsened after every use, and there are no adequate sterilization techniques that do not diminish the mask's quality.[87] This is a huge flaw in the economic model, as it leads to increased waste and places a significant financial burden on individuals and healthcare systems alike.

The environmental impact of disposing of single-use masks is what makes them so problematic. When facemasks undergo weathering from exposure to elements such as air and water, they release concerning amounts of microplastics into the environment.[88] These have the potential to enter food crops through the soil in agroecosystems, potentially posing risks to human health and the broader ecosystem.[89] Inadequate waste management directly concerns the environment, as non-biodegradable plastics from disposable masks enter the ecosystem through landfills or littering and pollute both terrestrial and marine environments.[90] Littering of COVID-19 exposed products is responsible for a vicious cycle: this can further spread COVID-19 through secondary transmission as the virus can adhere on the surface of materials for 2 days or more.[91] In this crisis, the urgency for sanitation and protection reveals a critical flaw

[87] Cubas et al. 2023, 3.
[88] Oliveira et al. 2023, 3.
[89] Rai et al. 2023, 6.
[90] Cubas et al. 2023, 1.
[91] Tsukiji et al. 2020.

in the economic life cycle of our healthcare infrastructure and blatantly displays our unsustainable reliance on single-use medical supplies.

The methods employed for disposal and treatment of single use medical supplies are often inadequate, and cause great environmental damage. The most common waste disposal method of municipal solid waste is through landfill, and incineration is the most prevalent way to dispose of medical waste, as discussed in Chapter 2. In emerging economies, medical waste is often improperly disposed of by being combined with municipal solid waste, which puts humans and stray animals at a high risk of exposure to pathogens.[92] Incineration is also popularly used in emerging economies due to a lack of availability for alternative methods, and this greatly increases emissions of greenhouse gasses and toxic gasses. Incineration makes microplastics in face masks airborne, therefore diminishing the quality of the air we breathe.[93] It is also performed at 900 to 1200 degrees Celsius according to WHO guidelines in order to adequately destroy pathogens, which creates an extreme amount of carbon emissions.[94] Ironically, microplastics negatively impact several ecosystem services of public health, despite being used in materials meant to improve public health. These ecosystem services include (but are not limited to) agriculture, air quality, water quality, and biodiversity. Developing sustainable alternatives or innovative methods for safely reusing medical-grade masks could not only address these economic concerns, but also contribute to environmental conservation and the overall efficiency of healthcare practices.

The Circular Economy. The onset of the pandemic spurred an unprecedented surge in the production of medical equipment and personal protective equipment (PPE) worldwide, driven by the urgent global necessity for these resources. Much of the economic stressors on healthcare

[92] Tushar et al. 2023, 2.
[93] Rai et al. 2023, 4.
[94] Klemes et al. 2020.

which negatively impact the environment are related to the mass production of medical supplies, the inability to recycle because of the possibility of COVID-19 transmission, and the use of unsustainable materials that pollute the environment with microplastics. These are all flaws of a linear economy: this is the dominant economic model, which involves the disposal of a product after its use, leading to the generation of substantial waste without adequate consideration for environmental consequences. This linear model's shortcomings have become glaringly evident in the context of the pandemic, as the rapid production and disposal of medical supplies contribute to environmental pollution, particularly through the proliferation of non-biodegradable materials such as microplastics.

In contrast, the circular economy presents a paradigm shift in economic thinking, prioritizing resource efficiency, waste reduction, and sustainability. A circular economy is an economic system that prioritizes the continual use, recycling, and regeneration of materials to minimize waste and promote sustainability, emphasizing the use of biodegradable materials and avoidance of overproduction.[95] Circular economic principles would be extremely useful in combating the medical waste challenges exacerbated by COVID-19. Initiatives aimed at promoting mask recycling, advanced sterilization technologies, or the creation of more durable and washable materials are all potential solutions to mitigate the economic and environmental impact of single-use medical supplies, and will be discussed further in Chapter 5.

The Life Cycle Assessment (LCA) is often used to assess the environmental impacts of a process, product, or service, along all stages of manufacturing, distribution, and disposal, and is a useful tool in analyzing the sustainability flaws of healthcare products.[96] Unlike N95 and surgical face masks which are greatly responsible for plastic pollution, an LCA of reusable face masks

[95] van Straten et al. 2021.
[96] Laca, Herrero, and Díaz 2011.

revealed that they reduced waste by 85% and contributed to climate change 3.39 times less than disposable masks.[97] One study found that it is possible to reuse the same disposable face mask after sterilization via autoclaving while still maintaining its breathability and shape, and LCA revealed that this results in a 58% reduction in carbon footprint.[98] Biopolymers, derived from renewable sources, offer a potential solution by providing a more eco-friendly alternative to single-use plastics, as they have a shorter life cycle.[99] Technological advancements such as pyrolysis, depolymerization, and gasification should be further explored as avenues towards a circular economy, as these thermo-chemical conversion techniques can create value-added products that can be put back into the economy as resources.[100]

Surprisingly, one way that the pandemic made positive strides away from the linear economy model was the implementation and popularity of digital health solutions. Telehealth, in particular, emerged as a transformative approach to healthcare delivery, offering remote consultations, diagnosis, and treatment options through digital platforms. This transition towards telehealth represents a significant step towards a circular economy model by minimizing waste and emissions associated with traditional healthcare practices. Unlike conventional in-person healthcare visits that often involve travel, paper-based documentation, and disposable medical supplies, telehealth reduces the need for physical infrastructure, transportation, and resource-intensive processes. By leveraging digital technologies, telehealth not only reduces the carbon footprint of healthcare delivery but also enhances efficiency, accessibility, and patient outcomes. Furthermore, telehealth promotes a more sustainable and resilient healthcare system by decentralizing care, reducing healthcare-associated infections, and empowering individuals to

[97] Rai et al. 2023.
[98] Laca, Herrero, and Díaz 2011.
[99] Cubas et al. 2023.
[100] Rai et al. 2023.

take proactive control of their health in a convenient manner. As we continue to embrace telehealth and other digital health solutions, we move closer towards a circular economy model that prioritizes resource efficiency, environmental sustainability, and improved public health outcomes.

Our linear economy shows a lack of resilience in dealing with crises of scarcity and carrying capacity in healthcare. Utilizing circular economic techniques will ease both of these issues: there would be less demand for PPE because it would not be single-use, and there would consequently be decreased waste associated with its production because it would be produced less and recycled back into the economy. The extensive benefits of researching ways to recycle and save materials in the healthcare sector cannot be overlooked. It will be discussed in more detail in Chapter 5, where solutions to the pandemic's negative environmental impacts are analyzed.

Chapter 4. Environmental Health and Public Policy

The global outbreak of COVID-19 prompted unprecedented and swift public policy responses worldwide. Governments across the globe implemented a variety of measures to curb the spread of the virus, protect public health, and mitigate the socio-economic repercussions of the crisis. However, the focus of policymakers rested solely on immediate health concerns and economic stability, making unintended consequences of the pandemic on the environment increasingly apparent. Chapter 4 delves into the interaction between public policy and environmental health during the pandemic, specifically its negative impacts. From changes in waste management practices to alterations in transportation patterns, the repercussions on ecosystems, air quality, and natural resources have been substantial. As we navigate the

complexities of a post-pandemic world, understanding the environmental trade-offs of the policy decisions made during the crisis is imperative for fostering sustainable and resilient countries. By explaining the functionality of the government in relation to public health and examining key policy domains**,** this chapter aims to provide a comprehensive analysis of how these measures impact the environment.

The Structure of Government Public Health Defenses. The government plays an integral role in safeguarding public health and the environment and is responsible for the formation and implementation of policies that can address each domain without undermining the other. Governmental agencies must create and enforce regulations that ensure the well-being of citizens and the preservation of the environment simultaneously. The main goal is to have public health policy that aligns harmoniously with environmental policies that seek to protect ecosystems, air and water quality, and biodiversity. Policies that protect the environment have inadvertent positive impacts on public health, as they lead to cleaner, healthier conditions for both ecosystems and humans. However, policies that protect public health can come with both positive and negative externalities towards the environment: for example, lockdowns slowed economic production and reduced air pollution, but mask mandates created excessive waste beyond the capability of waste management facilities to handle, resulting in rampant microplastic pollution. Because of its global scale, the COVID-19 pandemic provides a unique opportunity to analyze policy addressing the same crisis across several government bodies and identify both successful and failing common threads.[101]

In every country around the world, controlling the spread of the COVID-19 virus was the number one priority of policymakers. This manifested commonly in policies such as school closures, stay-at-home orders, curfews, mandated shutdowns of in-person procedures, closure of

[101] Liu and Geva-May 2021, 133-134.

public transport, contact tracing, travel restrictions, investment in vaccine research, and income support for families struggling with the economic shutdown.[102] One study conducted on 90 countries to analyze the effectiveness of these common policies found that strictness of contact tracing and testing were most effective in reducing the virus, and emergency investment in healthcare was also extremely valuable in reducing the stress on the healthcare system.[103] The role of governments in slowing the spread of the virus and providing relief to their citizens became vital during the pandemic.

Much of the policy recommendations were provided by the World Health Organization (WHO), which is a specialized agency of the United Nations responsible for international public health. The WHO is reliant on the collaboration of its member states and does not have the power to enforce its recommendations. There are also national public health agencies that were integral parts of the policies surrounding COVID-19. The United States, for example, has the Centers for Disease Control and Prevention (CDC), which is a public health organization that provides guidance, data, and recommendations informing federal, state, and local responses to the pandemic. The National Institutes of Health (NIH) were also integral parts of United States public policy during the pandemic, most notably their director of the National Institute of Allergy and Infectious Diseases at the time, Dr. Anthony Fauci. Dr. Fauci worked on the White House Coronavirus Task Force under President Trump and the White House COVID-19 Response Team under President Biden, and his recommendations were greatly anticipated by the federal government and the general public. Many decisions were also left up to state governments in the United States, such as the implementation of mask mandates and curfews.

[102] Chung et al. 2021.
[103] Ibid.

Environmental Impact of Policy During the Pandemic. In general, the pandemic turned the focus of policymakers on combating the spread of the COVID-19 pandemic, unfortunately at the expense of environmental protection policies. One study found that periods of time when a country was experiencing increased severity of COVID-19 infections correlated with a decrease in governmental environmental activity, and countries with weaker environmental policies before the pandemic were particularly volatile.[104] Therefore, the pandemic was a very difficult time to implement environmental policies. Getting governments to administer policies safeguarding the environment has always been difficult, as much of the environmental impacts we seek to reverse will not directly affect the majority of humans in their lifetimes. One study investigating the social perception of the environment during the COVID-19 pandemic found that survey participants were more likely to notice short-term positive impacts of the pandemic on the environment. However, people generally avoided thinking about the larger problems being exacerbated by temporary pandemic solutions, as the overproduction of plastic waste and other negative impacts of the pandemic were not reported.[105] Even though environmental degradation has disadvantages for public health, these are not perceived and therefore rarely prioritized. The depletion of natural resources and burning of fossil fuels contribute to a massive problem that will only fully manifest itself decades in the future, and by then these problems will be too late to solve.

On the other hand, the COVID-19 pandemic was an extremely time-sensitive issue that created an immediate imminent danger to the lives of every human on earth, which means that it quickly became a global priority and hot topic in public elections. Many policies were dedicated to relieving the socioeconomic strains of the pandemic on households. Policymakers rolled out

[104] Rosell 2023, 847.
[105] Hidalgo-Triana et al. 2022, 2.

economic support packages aimed at mitigating the impact of lockdowns and stimulating the economy to pre-pandemic levels. These measures of "economic recovery spending," depending on their nature, can exert lasting effects on the environment, either positively or negatively. Notably, governments have substantially increased recovery spending, totaling approximately 2.14 trillion USD within the first 18 months since April 2019, primarily driven by high-income countries.[106] However, only a mere 24% of this expenditure is categorized as "green," meaning it contributes to strengthening ecosystem services and addressing critical environmental concerns such as climate change, biodiversity loss, and air pollution. For policymakers, stopping the immediate threat of COVID-19 was a no-brainer, even with setbacks in environmental policy that will be very difficult to overcome in the long run.

As discussed in Chapter 1, there were many positive short-term impacts of the restrictions necessitated by the pandemic, several of which were the result of government policies and interventions. Lockdowns reduced human activities and the need to commute, meaning that air pollution decreased and water quality improved.[107] However, the negative impacts of the pandemic on the environment due to the decisions of policymakers cannot be ignored, specifically in the realm of single-use plastic. Governments all over the world implemented mask mandates which required a mask to be worn in public. In spite of that, there are no focused waste management strategies addressing COVID-19, nor are their policies mandating the use of biodegradable or reusable materials. Many previous single-use plastic phaseouts occurring before the pandemic needed to be put on hold, such as China's proposed six-year plan announced in January 2020.[108] There is also a lack of policy addressing excessive pollution due to single-use face masks containing microplastics. As previously mentioned, the degradation of microplastics

[106] Vardon et al.
[107] Ibid.
[108] Kencono 2023, 15.

is dangerous for public health, as it contaminates the soil we use to grow our food and can enter the air we breathe. Overall, there is clearly a lack of policy addressing microplastic pollution, despite mask mandates exacerbating the issue.

As discussed in Chapter 3, the need to strengthen healthcare infrastructure and respond to the COVID-19 pandemic prompted sizable financial allocations and investments in medical supplies, research, and healthcare facilities. While these investments were central to managing the immediate health impacts of the pandemic, they also resulted in unintended environmental consequences. Increased production of medical supplies, including single-use PPE and disposable medical items, contributed to a surge in plastic waste. Moreover, the fast pace of healthcare infrastructure development necessitated by the pandemic resulted in excessive resource extraction and energy consumption, which calls into question the long-term sustainability of increasing healthcare infrastructure. The United States healthcare system in particular is already massive, which means that there should be efforts to resolve inefficiencies at a systemic level, rather than continuing the unmanageable growth of healthcare assets.

Relaxation of Environmental Protection Policies. The COVID-19 pandemic prompted unprecedented changes in public policy worldwide, with governments scrambling to address the health crisis and mitigate its socio-economic impacts. However, these policy shifts have inadvertently led to increased rates of deforestation, posing significant threats to global forest ecosystems, and consequently, public health. As was previously explained in Chapter 1, deforestation increases the likelihood of zoonotic disease spillover and could therefore be a cause of the next great pandemic, creating negative implications for public health. Governments around the world have grappled with limited monetary resources and competing priorities, leading to the

relaxation of environmental regulations and diversion of funds away from forest conservation efforts.[109]

Forests play a crucial role in sustaining life on Earth, providing essential services to humanity and supporting the livelihoods of over 20% of the global population.[110] Yet, the relaxation of government policies has facilitated excessive harvesting of timber and other forest products, exacerbating deforestation rates. Moreover, the increased demand for hygiene and sanitary products to prevent viral spread such as tissue paper, toilet paper, paper towels, and alcohol-based hand rub has further strained forest resources.[111] The surge in toilet paper sales, which saw a 700% increase at the onset of the pandemic, also intensified pressure on forests and increased demand for deforestation.[112] Additionally, wood pulp and fiber are also utilized in the production of masks, paper gowns, and other personal protective equipment (PPE), showing how the pandemic further fueled deforestation.[113]

Furthermore, the pandemic has seen a rise in crime cases related to natural resources, specifically illegal logging and deforestation, yet there has been a lack of effective policy measures to prevent such illegal activities. Governments' diversion of public funds to the health sector has left forests vulnerable, with inadequate budget allocation for protection and conservation efforts. For instance, in Brazil deforestation rates surged within the pandemic period, as 57 amendments made to their legislation in 2021 weakened policies in favor of forest conservation efforts. Additionally, the Indonesian government altered its past policies to restore abandoned peatland, diverting it for agricultural use to address food shortages during the pandemic. Peatlands are known to be rich with carbon, so their destruction greatly increases

[109] Singhal et al. 2024, 2.
[110] Ibid., 2.
[111] Food and Agriculture Organization 2020.
[112] Garbe, Rau, and Toppe 2020.
[113] Singhal et al. 2024, 6.

carbon emissions, contributes to global warming, and threatens biodiversity even more so than deforestation.

In addition to the relaxation of environmental protection policies and law enforcement regarding deforestation, policymakers also reallocated budgets away from environmental sectors, therefore opening avenues for environmental degradation. Many recovery packages announced by governments globally across 64 cases and in 22 countries included withdrawals of environmental protection budget, which further exacerbates the challenges faced by forest conservation efforts.[114] For example, countries like Mexico and Ecuador in Latin America have already announced budget cuts in the natural resource management sector, compromising forest protection initiatives.[115] In many cases, funds earmarked for environmental protection have been redirected to other sectors, undermining efforts to combat deforestation and preserve vital forest ecosystems. Ultimately, policies that impact the environment are inseparable from the conversation of public health. As Chapters 1 and 2 discussed, governments have been preparing for a global pandemic for years now, as our constant environmental disruption increases the likelihood of zoonotic disease transfer to humans. Our mistreatment of the environment created this public health emergency, and policymakers' focus on the COVID-19 emergency caused further mistreatment of the environment. This shows a perpetual feedback loop that will spiral into further environmental degradation and public health consequences without holistic policy interventions that address public health, socio-economic development, and environmental conservation all at once.

Case Study: Pandemic Fiscal Policy and Climate Change. During the pandemic, fiscal policy initiatives saw an unprecedented increase, with fiscal spending surpassing levels observed

[114] Friedlingstein et al. 2022.
[115] Singhal et al. 2024, 7.

during the 2007-08 financial crisis by a factor of four.[116] As was previously discussed, this spending often did not consider environmental externalities and was primarily focused on getting the economy through the public health crisis without huge economic consequences. Fiscal policies laid out by governments during the pandemic fell short of adequately addressing environmental factors, climate change being a prime example. One study analyzing 8,000 government policies across 88 countries revealed that only a fraction of economic recovery spending, approximately $279–334 billion USD or 9.7–11.1%, directly improved climate change adaptation and resilience, which is not enough to adequately address climate adaptation needs.[117] Adaptation to climate change refers to the process of adjusting to the impacts of climate change over time, while resilience entails the ability to withstand and recover from those impacts, ensuring the maintenance of essential functions and systems. Additionally, a considerable portion of government recovery spending, approximately 27.6–28%, may have negatively contributed to climate change adaptation and resilience, potentially solidifying outdated and low quality infrastructure.

Climate change adaptation and resilience are integral components of public health resilience, and investments in resilient infrastructure can be important for safeguarding human health during and after crises. Resilient infrastructure, such as robust healthcare facilities, reliable water and sanitation systems, and climate-resilient housing, can mitigate the adverse health impacts of extreme weather events, natural disasters, and disease outbreaks. Additionally, climate-resilient ecosystems contribute to food security, clean air and water, and protection against vector-borne diseases, thereby enhancing public health outcomes. By prioritizing climate change adaptation and resilience in fiscal policies, governments have the opportunity to "build

[116] Sadler et al. 2024, 271.
[117] Ibid., 271.

back better," strengthening societal resilience to future crises and safeguarding public health for generations to come.[118] By integrating climate resilience into pandemic recovery efforts, governments can not only address immediate health concerns but also lay the foundation for a healthier, more resilient society in the long term.

Future Global Collaboration. Developing environmental policy during the pandemic, both to address ongoing environmental issues and prevent the worsening of issues due to the emergency COVID-19 protocol, proved to be extremely difficult. However, there is a silver lining to the global extent of COVID-19's reach. The shared experience of the pandemic showed how interconnected global societies are, and highlighted the need for a collective response to global public health emergencies. Calls for a "green recovery" have gained momentum, advocating for economic stimulus packages that prioritize investments in renewable energy, conservation efforts, and sustainable development. This would repair economies that took massive hits during the pandemic from the ground up, as principles of sustainability would be the foundation of their success.[119] The lessons learned from the pandemic offer a unique opportunity to build a more interconnected and sustainable world through international cooperation.

Chapter 5. Future Avenues Towards Sustainability in Healthcare

The COVID-19 pandemic's influence on the relationship between the environment and public health cannot be understated. Miraculously, the halt in global economic activity due to mandated lockdowns and other activity-hindering policies resulted in a rejuvenation of the environment through a reduction of air and water pollution. This has direct positive impacts on society, as these are vital ecosystem services for humans and their cleanliness is paramount to

[118] Ibid., 274.
[119] Yale Sustainability 2021.

human health. However, the lockdown was short lived, as were its positive effects. How do we find a way to preserve these successes without taking extreme measures that were required for the pandemic?

Additionally, the pandemic necessitated the use of single-use disposable items, especially PPE, and overwhelmed the healthcare system and medical waste facilities. This exacerbated pollution of the air and soil with microplastics and other harmful compounds, as the high volumes of waste were often not properly disposed of or managed. Pollution has lasting negative impacts on human health, as polluted soil and air can hurt pollinators and contaminate food crops, therefore adversely affecting food justice. How do we correct the design flaws in PPE to prevent pollution? How do we foster preparedness in the healthcare system to prevent overcapacity that leads to medical waste? Most of all, how can we prevent the reoccurrence of another pandemic of this nature altogether using environmental restoration strategies? These are the questions that will be answered in Chapter 5 with my own policy recommendations, economic reforms, and healthcare transformations.

Converting the Linear Economy to Circular. As explained in Chapter 3, one of the greatest flaws in the healthcare system is the lack of responsibility for the waste accumulated. Single-use items were used more than ever to prevent the spread of COVID-19, but this simply exacerbated a larger design flaw within healthcare regarding waste. Other industries have felt public pressure to reduce their carbon and plastic footprints, but the healthcare industry has not faced this scrutiny enough for significant action to be taken. In 2018, the European office of the World Health Organization published a comprehensive report explaining the risks and rewards of converting to a circular economy in healthcare: it concluded that waste reduction and recycling in healthcare, product life extension, reduced use of landfills and incineration, and substitution or

reduced use of hazardous materials will have positive health impacts.[120] It is important for policies to provide support for researchers looking into the most efficient, safe, and health conscious ways to recycle materials and treat waste in healthcare.

Another way that a circular economy can mitigate waste accumulation in healthcare would be through the development of a biodegradable face mask with comparable filtration properties. As discussed in Chapters 1 and 3, medical face masks used by healthcare workers and the general public during the pandemic contain microplastics that degrade and disperse into the earth and air. Reusable masks are a much more environmentally friendly option, but their filtration properties are not as predictable because they can be made out of many different textiles. We need biodegradable medical-grade face masks that will not harm ecosystems. One potential solution would be using bioplastic, which are materials made of raw materials from renewable sources such as corn, cassava, or cellulose, and have shorter life cycles than other plastics of fossil origins.[121] One study on the degradation of a face mask made of polylactic acid (PLA) under varying pH conditions found that PLA masks could be considered a slightly greener option under emergency circumstances as they do not generate secondary microplastic pollution; however, these masks do not fully degrade fast enough to be considered an exhaustive fix.[122] Biodegradable plastics are not the perfect solution, as these plastics often need hyper-specific conditions to break down naturally, but they can still be a step in the right direction. Policymakers should fund further research into biodegradable materials to support the effort to control waste in healthcare.

Another essential component of the circular economy solution is the ability to recycle all economic outputs. Efforts to recycle face masks during the pandemic were greatly slowed due to

[120] World Health Organization 2018.
[121] Cubas and Vieira et al. 2023, 9.
[122] Soo et al. 2022, 4.

concerns about viral transmission. However, one promising avenue for implementing circular economy principles involves repurposing face masks for use in construction materials such as concrete and pavement.[123] Face masks are predominantly made from polypropylene, a material commonly used in construction applications such as concrete, pavements, asphalt, and hot mix asphalt. One study found that shredded face masks and incorporating them into the base layers of pavements with recycled concrete aggregate met the stiffness and strength requirements for base and subbase layers of pavements with up to 3% shredded mask concentration.[124] Overall, it was estimated that utilizing face mask waste in just 17% of road construction projects can help mitigate the challenges associated with microplastic pollution, offering a sustainable solution to both environmental and infrastructure needs.[125] The implementation of circular economy strategies will create resiliency in the healthcare industry and prevent waste management systems from reaching overcapacity, as materials are designed to be reintegrated back into the supply chain or safely decomposed in the environment.

Improvement of Medical Waste Treatment Methods. Circular economy strategies can be difficult to conceptualize and implement, especially because there are still research gaps and no perfect replacement for current disposable face masks developed. If policymakers want to start smaller, they can look into improving methods of medical waste treatment. Improving medical waste disposal techniques is paramount for safeguarding both environmental integrity and public health. Inadequate management of medical waste poses significant risks, including the spread of infectious diseases, contamination of air and water sources, and the proliferation of hazardous chemicals and pollutants. By implementing more advanced and environmentally responsible waste disposal methods, such as sterilization technologies, chemical treatments, and autoclaving,

[123] Najafighodousi et al. 2023, 12584.
[124] Saberian et al. 2021.
[125] Najafighodousi et al. 2023, 12587.

healthcare facilities can effectively neutralize pathogens and reduce the potential for disease transmission. Policymakers should make efforts to phase out practices of landfill and incineration, because these create large amounts of waste without reducing it in a sustainable manner. There are many emerging sustainable methods of waste treatment to be explored, including decontamination via vaporized hydrogen peroxide, ozone, or ultraviolet light, and low heat technologies such as microwaving or autoclaving.[126] It is important to note that the best methods of waste disposal depend on the volume and type of waste being disposed of. Policymakers should make this information readily available to healthcare and waste disposal facilities in order to facilitate the transition to sustainable waste disposal. They should also reallocate budgets towards researching sustainable alternatives and funding implementation of sustainable waste treatment centers on a large scale. This will contribute to the resilience of the healthcare industry in the face of future public health crises and prevent environmental damage resulting from waste treatment overcapacity.

Healthcare Education and Accessibility as Preparedness. A major problem throughout the pandemic was the unwillingness of the public to listen to the advice of policymakers. Oftentimes, new waves of the virus would sweep through populations and infect vulnerable people because of ignorance and disregard for lifesaving social distancing measures. Another huge issue was the lack of accessibility to healthcare, because when people cannot receive medical treatment they are able to spread the virus further, therefore worsening the crisis. Educating the public on the importance of seeing their doctor, utilizing preventative healthcare to protect the population, and creating universal healthcare will keep the population themselves prepared for another pandemic, should it occur. Additionally, the education of the future

[126] Teymourian et al. 2021.

healthcare workforce on sustainability is equally important, as they have the power to implement green initiatives from the ground up.[127]

Educating the public on the importance of keeping up with their health can give the healthcare system a huge preparedness advantage in the event of another pandemic, and consequently reduce the environmental impact such an event would have. Regular practices of a healthy lifestyle and attending yearly physicals will reduce populations at a greater risk for health complications in the event of getting sick. It will also keep people informed about their health- for example, someone who regularly attends yearly physicals would know if they are asthmatic and extra vulnerable to COVID-19 symptoms, and they therefore would take extra precautionary measures to avoid getting sick. Keeping people informed about their health is an incredible way to prevent people from getting sick at all, therefore preventing the environmental conundrums created by COVID-19.

Additionally, access to healthcare can be a huge barrier for at-risk individuals, especially those whose health is disproportionately impacted by environmental pollution. For instance, the Bronx, New York has the poorest residents of any borough in New York City, but children in the Bronx have the highest rates of asthma hospitalizations in the country.[128] Based on this fact, the people who need healthcare the most have the least ability to receive it, because the United States does not provide universal healthcare. Multiplayer systems, introduced in Chapter 4, contribute to the inefficient and often inequitable separation of public health and medical care, and discussed in Chapter 1. For Americans who did not have insurance or health coverage, their diagnosis and treatment were delayed, therefore increasing the possibility of viral transmission. Studies estimate that a universal healthcare system in the United States would have saved

[127] Sherman et al. 2020, 8.
[128] Pala et al. 2019.

roughly 212,000 lives just in the year 2020, and 105.6 billion USD of medical expenses would have been avoided.[129] Research shows that countries with stronger universal health coverage actually fared better during the pandemic, having lower numbers of infections and deaths.[130] This shows that universal healthcare made countries more prepared to handle a public health crisis, reducing their environmental impact alongside their sick and deceased numbers.

Another recommended solution to prevent the overcapacity of healthcare during a future pandemic would be the reoutlining of an emergency strategy in the event of another national or global health crisis. The stark reality of the COVID-19 pandemic exposed vulnerabilities in healthcare systems worldwide, from strained resources and overwhelmed medical facilities to logistical challenges in the distribution of essential supplies. A comprehensive emergency healthcare plan is essential to avert a recurrence of this situation, as was discussed in Chapter 2 regarding past pandemics. This plan should have robust strategies for resource allocation, surge capacity, and rapid response coordination. Adequate stockpiling of medical supplies including PPE and pharmaceuticals should be prioritized. Clear protocols for the deployment of healthcare workers, responsive testing and vaccination campaigns, and seamless outlets to deliver information would be crucial components. It is also fundamental to foster international collaboration through organizations like the WHO, as expertise, resources, and technology can be shared. An emergency healthcare plan acts as a shield against the potentially devastating impact of another global pandemic, and ensures that all nations are equipped and organized in their approach to handling such a scenario.

Preventative Measures against Zoonotic Disease Transmission. COVID-19, like many other infectious diseases, is zoonotic in nature, originating from animals and being transmitted to

[129] Galvani et al. 2022, 1.
[130] Saengtabtim et al. 2023.

humans. As extensively discussed in Chapter 1 and reiterated throughout this thesis, the likelihood of zoonotic disease transmission escalates with environmental degradation, especially through practices such as deforestation. While numerous solutions focus on enhancing healthcare infrastructure and response mechanisms, this proposal suggests addressing the root cause of pandemic diseases. By prioritizing efforts to prevent the spillover of zoonoses in the first place, we can significantly diminish the risk of global health emergencies and thus mitigate the likelihood of future pandemics. Implementing comprehensive strategies that target the agriculture industry, forest conservation efforts, and zoonotic disease hotspots can serve as crucial preventive measures against the emergence and spread of zoonotic diseases, safeguarding both human and environmental health for generations to come.

Targeting the agriculture industry presents a promising avenue for reducing the spillover of zoonotic diseases and thus preventing future pandemics. The intensification of animal agriculture, or increasing efficiency per unit of land area through infrastructure investments, has been thought of as an avenue to decrease deforestation. However, efficiency leads to cost reduction, which decreases market price and increases consumer demand, therefore resulting in rebound effects of increased deforestation.[131] Therefore, semi-intensification of agriculture must be coupled with additional regulatory policies for this to remain effective. Recent research indicates that worldwide shifts in diets hold the potential to effectively counteract persistent deforestation patterns, yielding 5 to 11 gigatons of carbon dioxide removal annually across 5 to 12 million square kilometers.[132] Achieving such dietary changes requires more targeted interventions such as implementing rewards or incentives, possibly through taxation policies. Policymakers should enable measures with standards for regulating supply and demand of

[131] Hakek 2022, 3.
[132] Ibid., 4.

products requiring excessive land use, such as restricting imports of soybeans, beef, palm oil, and other products linked to deforestation.[133] Some sources have called for transitions to less land-intensive animal products to reduce deforestation, such as pigs or chickens. However, while cattle farming contributes to land use and deforestation, a shift towards increased chicken consumption could exacerbate risks of zoonotic disease emergence due to elevated confinement and antibiotic use.[134] Therefore, there should be more focus on overall gradual dietary shifts toward plant-based meals, as most animal agriculture is linked to zoonotic disease spillover.

Building upon previous explorations in Chapter 4, zoonotic disease transmission can be mitigated through blatant deforestation regulations and reforestation policies by governments. Through increasing natural vegetation, roughly ten years' worth of human-caused emissions would be captured by 2050, therefore aiding in both habitat and biodiversity restoration.[135] Conservation initiatives enforced by governments are also crucial in preventing continued deforestation, both illegally and legally. Unfortunately, due to the global nature of our economy as outlined in Chapter 3, conservation efforts can often result in the movement of a forest product's harvesting where conservation laws aren't as strong. Therefore, this solution will require conservation initiatives on a global scale through the collaboration of nations, and a unified commitment to taking any actions necessary to stop future zoonotic pandemics regardless of economic impacts.

In addition to large scale global policies, special attention should be paid to the source of pandemics. These can often be identified very easily as emerging disease hot spots: these locations only account for 4% of the globe, yet they are responsible for 60% of the global risk for

[133] Vora et al. 2023.
[134] Hayek 2022.
[135] Ibid., 3.

zoonotic disease spillover.[136] Community designed interventions in these areas can reduce zoonoses contraction, such as restricting to human contact with wildlife through physical barriers along forests or penalties through fines. Additionally, as learned in Chapter 1, extensive sources hypothesize that COVID-19 was transmitted to humans through illegal wildlife markets. Law enforcement against these markets will not only protect wildlife from human encroachment, but also reduce the likelihood of zoonotic disease transmission. Funding virology research will also give clues into what microbes are likely to have the ability to infect humans based on their current hosts[137], and policies can be geared towards avoiding human contact with those viruses specifically.

Conclusion. Chapter 5 delves into future pathways toward sustainability in healthcare, addressing the inextricable relationship between environmental conservation and public health resilience. From circular economy principles to advanced medical waste disposal techniques and enhanced healthcare accessibility, there are many ways to mitigate environmental degradation and prevent future pandemics through policies, research, and other initiatives. Embracing circular economy strategies in the healthcare industry and advancing medical waste treatment will prevent negative impacts on the environment, especially during healthcare emergencies. Investing in healthcare education and accessibility creates resilience against future health crises by fostering healthy populations. Targeting the causes of zoonotic disease transmission by reducing deforestation fortifies global health security and environmental sustainability. By integrating policy recommendations, economic reforms, and healthcare transformations, Chapter 5 looks toward a future where human health and environmental well-being are intrinsically linked, paving the way for a more resilient and sustainable world for generations to come.

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[136] Vora et al. 2023.
[137] Daszak 2012, 1884..

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