Cattle scourge no more

The eradication of rinderpest and its lessons for global health campaigns

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ABSTRACT. In 2011, the Food and Agriculture Organization of the United Nations (FAO) officially declared rinderpest eradicated. This cattle virus, which has historically had significant political, economic, and social consequences, is only the second infectious disease to disappear from the face of the planet due to concerted human actions. This paper explores the effects that rinderpest has had historically, chronicles the actions of the Global Rinderpest Eradication Campaign (GREP), and discusses the lessons that GREP can offer for combating other infectious diseases. I argue that rinderpest's unique viral characteristics made eradication particularly feasible, but that GREP's activities offer important lessons for fostering international cooperation on controlling infectious disease outbreaks.

Key words: Rinderpest, Global Rinderpest Eradication Program, One Health, animal health, human health, infectious disease control and eradication

On June 28, 2011, the United Nations held a special ceremony for an event so rare that it had only happened once before. On that day, the international community formally declared that humanity had eradicated rinderpest. Thirty years after the World Health Organization certified that smallpox no longer circulated freely, the United Nations announced that a concerted, comprehensive international campaign succeeded in stopping a virus from ever infecting another creature again.

Rinderpest, a disease that primarily infects cattle, caused an untold number of human and animal deaths, devastated local economies when it appeared, and dramatically altered world history—yet the campaign to eradicate the disease received relatively little attention. It is true that rinderpest does not infect humans, and the disease disappeared from Europe and the Americas by the 1930s, but rinderpest's consequences for both humans and animals are undeniable.

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As such, successfully eradicating the disease could improve the lives of millions of people around the world. In addition to the tangible benefits that arise from rinderpest's eradication, the campaign to wipe out this virus can offer lessons to the global community about our understanding of international cooperation, the connections between human and animal health, and the intersection between international politics and global health.

This article posits that the global campaign to eradicate rinderpest offers three important lessons for the international community: the importance of scientific and technical prowess; the necessity of appreciating local political, economic, and social contexts for implementing such campaigns; and, the wisdom of incorporating campaigns into existing programs and organizations when possible. These lessons in some ways reinforce lessons from the smallpox eradication campaign decades earlier, but also demonstrate a unique understanding of international order in the contemporary era. In order to understand these lessons, it is imperative to first understand rinderpest itself, its historical effects, and the campaign to eliminate it from free circulation. It is also important to understand how disease eradication campaigns relate to the emerging notion of One Health and its understanding of the interplay between human and animal health.

The article begins by describing the basic facts about rinderpest before turning to a brief discussion of the virus' effects going back more than 3,000 years in the second section. The third section discusses disease eradication campaigns, marrying these insights with the literature on One Health. The fourth section details the successful efforts of the Global Rinderpest Eradication Campaign, in which the international community demonstrated the capacity to overcome serious obstacles to provide a global public good. The final section details the lessons the international community should learn from rinderpest's eradication for future global health programs.

The etiology of rinderpest

Rinderpest, derived from the German for cattle plague,[1] is an infectious viral disease with a recorded history going back to ancient Greece. While cattle are its primary victims, the disease can affect buffaloes and other even-toed ungulates.[2] The disease can infect both wild and domesticated animal populations, but outbreaks among wild populations are short-lived in the absence of susceptible domesticated cattle because the wild populations generally are not large enough to sustain the virus.[3] While it is genetically related to measles, rinderpest does not infect humans.

Rinderpest spreads solely from animal-to-animal. Urine, feces, saliva, blood, tears, and nasal secretions all contain the virus, and coming into direct or close contact can transmit it. These bodily fluids can also contaminate food and water supplies, creating another potential pathway for infection. Aerosolized droplets of the virus through coughs and sneezes also have the potential to cause the disease's spread, but only across short distances because of the weight and large size of the droplets. Since the virus is highly susceptible to heat and sunlight, it tends to not live long outside the body. Insects cannot transmit the virus, and there is no known animal that can harbor the virus without falling ill to it.

Once exposed, infected animals initially experience fever and constipation. This gives way to severe diarrhea, lack of appetite, discharges from the eyes and nose, enlarged lymph nodes, dehydration, and internal lesions. Infected animals are infectious for 1 to 2 days before and 8 to 9 days after clinical signs appear. Rinderpest is incredibly virulent, with morbidity rates of nearly 100 percent among exposed animals. Approximately 90 percent of infected animals die, generally within 6 to 12 days. Those that survive acquire lifetime immunity.

Prior to its eradication, there existed no effective treatment for rinderpest. On occasion, antibiotics could provide some supportive care, but this was rare. Instead, the most effective response was to slaughter infected animals to break the transmission chain. While effective, such a response meant significant economic loss for the herd's owner and the local community. The lack of effective treatment made prevention measures like vaccination and quarantine all the more important.

Since there existed no effective treatment for rinderpest, scientists turned their attention toward developing a vaccine to prevent the virus' spread in the first place. Since all rinderpest viruses share the same serotype, there was need for only one vaccine.[4] Experience had shown that animals that recovered from the disease retained lifelong immunity. Using this information, South African scientists in the late 1890s demonstrated that simultaneously giving cattle immune serum from a recovered animal and virulent blood from an infected one could confer immunity. This "serum-simultaneous" method proved more effective than previous efforts. Indeed, it played a role in helping eliminate the disease from Europe in 1928.[5] It held some significant drawbacks, though. The "serum-simultaneous" method could infect cattle with rinderpest itself if they had weakened immune systems. Also, because it used blood directly from other animals, it could spread other blood-borne illnesses.

Efforts to find a more effective vaccine continued throughout the first half of the twentieth century. J. T. Edwards of the Imperial Bacteriological Laboratory in Izatnagar, India (now the Indian Veterinary Research Institute) created a live-attenuated vaccine in the 1920s, but it still held the risk of spreading the disease to animals with weakened immune systems. The United States and Canadian governments collaborated on developing rinderpest vaccine on Grosse Île, Canada, during World War II, as they feared Axis powers could use the disease as a biological weapon. After the war's end, the newly formed Food and Agriculture Organization of the United Nations made rinderpest control and vaccination one of its top priorities.[6]

In the 1950s and 1960s, Walter Plowright conducted research at the East African Veterinary Research Organization in Muguga, Kenya, on rinderpest vaccines. Drawing on Albert Sabin's technique for making a polio vaccine, Plowright relied on cell cultures to weaken the virus. Plowright would weaken the virus in a cell culture of calf kidney cells, remove it, and place it in a fresh cell culture. After repeating the procedure 95 times, Plowright had a vaccine that did not infect injected cows with rinderpest (including those with weakened immune systems); in addition, the vaccine conferred immunity, and could be easily replicated.[7] Plowright's vaccine gave rise to mass vaccination campaigns throughout Africa and Asia, but its usefulness was limited because it had to be stored and kept at low temperatures to retain potency. In the 1980s, scientists introduced Thermovax, a rinderpest vaccine similar to Plowright's but one that could survive at ambient tropical temperatures for up to four weeks.[2] This innovation made mass vaccination campaigns in hot climates technically feasible.

Rinderpest in history

The earliest reports of cattle plague go back to the siege of Troy in 1184 BCE. William Youatt, one of the founders of the Royal Agricultural Society of England and a prominent veterinary surgeon, wrote a book in 1838 that describes cattle during this time experiencing "a shivering fit, followed by unnatural heat, extreme thirst, difficulty of breathing, and general debility" (p. 352).[8] The Food and Agriculture Organization has linked rinderpest to the fall of the Roman Empire, Charlemegne's conquest of Europe, the French Revolution, and the impoverishment of Russia.[9] More recently, though, Japanese geneticists found that rinderpest did not become a distinct disease until around the year 1000. Before then, rinderpest and measles were virtually identical.[10] This distinct virus likely developed on the steppes in Central Asia among oxen, and eventually spread throughout Asia and to Europe and Africa. Aside from brief outbreaks in Brazil in 1920 and Australia in 1923, rinderpest never took hold in the Americas, Australia, or New Zealand.

Efforts to stop the spread of rinderpest began in the early eighteenth century. In 1711, Bernardino Ramazzini began experimenting with setons, or strips of cloth contaminated with the rinderpest virus, as a way to protect cattle. Around this same time, Giovanni Maria Lancisi countered that the better technique was to kill all sick and infected animals instead of waiting for the development of a remedy or preventative agent.[11] Lancisi, Pope Clement XI's personal physician, was unique in that he did not believe that the disease arose from miasmas, astrology, or divine retribution. He urged priests not to rely on prayer to eliminate the virus, but instead had them exhort their parishioners to slaughter sick cows and bury the carcasses in lime. Failure to adhere to these guidelines was punishable by life imprisonment or drawing and quartering.[12] These efforts, while effective to some degree, could not stop the virus' spread across Europe, and the continent experienced at least three major rinderpest epidemics: 1709–1720, 1742–1760, and 1768–1786.[13] Fisher estimates that 200 million cattle died during these European outbreaks.[14] The disease's effects were so severe that they inspired the creation of the world's first college of veterinary medicine. Henri Bertin, France's Controller-General of Finances, gave money to Claude Bourgelat in 1762 to establish the school in Lyon, France, to stop the spread of rinderpest through the country's rural areas. Within 20 years, nearly every other European state followed France's lead and set up its own veterinary medicine school.[15]

Rinderpest continued to spread during the nineteenth century with devastating effect. When the virus arrived in Egypt in 1841, it killed 75 percent of the country's cattle and buffalo.[16] In 1865, rinderpest reappeared in England after many years, prompting a flurry of accusations about its source. Some blamed Russia, tracing the disease to 13 cattle brought to England via Estonia on May 23rd of that year. Others blamed it on Austro-Hungarian cattle brought to England via Germany and the Netherlands. Interestingly, a group of English cattle traders argued that the disease originated in England itself. They feared that government officials would restrict international trade, and thus deprive the traders of their livelihood, if they believed that the disease had come from outside the

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country. The Cattle Plague Commission did indeed make such a recommendation to the government in 1865 and 1866, but the Liberal Government headed by Lord Palmerston initially opted instead for relatively lax regulations enforced solely at the local level so as not to interrupt commerce.[17] By the time the outbreak ended in 1867, it had cost the English economy more than £3.5 million, devastated the country's stock and dairy industries, caused meat prices to increase 20 to 25 percent, and helped to bring down the Liberal government.[17] Fisher described it as "the most dramatic episode in nineteenth-century British agriculture" (p. 215).[11] Another rinderpest outbreak in Europe in the 1920s encouraged the creation of the World Organization for Animal Health (OIE) in Paris as a means for sharing information and encouraging scientific collaboration.[9] It was not until 1928 that rinderpest finally disappeared from Europe. To achieve this, European governments had to agree to severe restrictions on the movement of cattle across borders, the immediate slaughter of any and all infected cattle, and the use of the serum-simultaneous vaccine.[4]

Rinderpest in Africa

Rinderpest had perhaps its most dramatic effects in sub-Saharan Africa. Van Onselen argues that rinderpest's significance arose in part because of the importance of cattle in African pastoralist societies. The cattle themselves were a significant sign of wealth, so any disease that wiped out cattle necessarily wiped out a community's wealth. Reader writes, "Cattle had long been accepted as a form of wealth that endowed their owners with power and authority. Almost instantaneously, rinderpest swept away the wealth of tropical Africa" (p. 590).[18] Even more importantly, though, cattle served as a fulcrum for a host of social and cultural exchanges.[19] Cultural identity and transmission, social relations, and societal order arose in part through the role that cattle played in these societies. They were more than beasts of burden and sources of food and nutrition; they were cultural totems that gave meaning to the people. The widespread and rapid death of cattle therefore threatened the very bases of stability within pastoralist communities.

In 1887, rinderpest made its first appearance in sub-Saharan Africa. That year, infected cattle from India were imported into Eritrea by the Italian government. The government wanted the cattle to help sustain its soldiers, who were fighting in neighboring Somalia.[20] Instead, local communities witnessed the first wave of rinderpest epidemics that gradually spread to the southern tip of Africa over the next decade. While disease epidemics were not necessarily unheard of in Eritrea and pastoralist communities, the devastation wrought by rinderpest was on a scale never before seen. Studying the effects of rinderpest on southern Africa in the nineteenth century, Phoofolo remarked, "While cholera attacked people, who died and left their property behind, the rinderpest spared the people to watch with utter shock and suspicion as their most valued means of livelihood perished dramatically" (p. 114). The cultural, economic, and social upheaval resulting from rinderpest epidemics made colonists fear that rebellions could be imminent. They responded by stockpiling weapons, asking colonial governments for additional troops, and arresting suspected local agitators. These actions in turn further entrenched colonial powers by expanding their governmental apparatuses and sapping local communities of leadership.[20]

As rinderpest moved south, it devastated more and more communities. The virus arrived in Tanganyika (modern-day Tanzania) around 1895, and its outbreak managed to break the economy, undermine many prosperous and advanced communities, and disrupt the local ecological balance.[21] When it finally reached Natal and Zululand in 1896, it killed more than 90 percent of all African-owned cattle. In response, Dlozi, a Zulu patriarch, lamented, "A man who has no cattle is an umfokazana, a person of no account. . .[and] now cattle are killed off, we are nothing" (p. 203).[22] As cattle herds died, local elders could not even perform ceremonies to call upon ancestors to protect them because they lacked the cattle necessary to offer as a sacrifice.[23] Making the situation even worse, rinderpest's arrival followed years of drought and plant pestilence.[21]

Race and rinderpest in Africa

Responses by the colonial government to disease outbreaks among Africans were often greeted with suspicion and mistrust. In South Africa, the colonial government erected a 1,600 kilometer barbed-wire fence from Bechuanaland (now Botswana) to the Cape-Natal coast, replete with police patrols and disinfection stations, in a vain attempt to prevent the pest's entry

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into South Africa.[17] Blame for rinderpest's spread quickly fell to the area's African herdsmen. White farmers alleged that African farmers failed to properly restrain their infected cattle, which then infected the cattle owned by whites. In response to the outbreak, colonial officials in late 1896 began a program to quarantine "promiscuous" African-owned herds to prevent them from spreading the disease to white-owned herds.

As a part of the quarantine program, African-owned herds and their herders were doused with harsh chemical disinfectants in an attempt to eliminate rinderpest.[22] The disinfectant had almost no effect on rinderpest, but it did lead to the destruction of large numbers of African-owned cattle.

The next year, colonial officials tried a new approach. Robert Koch, one of the fathers of serology and the recipient of the 1905 Nobel Prize for Medicine for his work on disease control and the development of vaccines, came to South Africa to address the rinderpest problem. He began a program that inoculated cattle against rinderpest with a serum taken from the gall bladders of infected cattle. Unfortunately, the serum only had limited effectiveness. More problematically, injecting healthy cattle with the serum temporarily induced signs of the disease. As a result, colonial officials who announced to black herd owners that they were coming to protect their cattle, appeared to herd owners to be infecting their cattle with the very disease against which colonial officials claimed to be eradicating. This led to suspicion and resistance among black cattle owners. Carton writes, "If the Europeans came to cure, they [black herd owners] asked, why was he 'bringing the disease nearer'? This question was often posed by black people in southern Africa, who suspected rinderpest was the 'white man's' weapon of death in 'the imperial apocalypse' wasting their land" (p. 204).[22]

Such dramatic interventions roused suspicions in other parts of Africa, too. When Cape Colony government officials decreed in March 1897 that all African-owned cattle should be shot and buried in order to stop the spread of rinderpest, pastoralist communities adamantly refused to acquiesce. They instead rebelled against the orders, inspiring such consternation among local officials that they refused to enforce the regulations.[24] Phoofolo notes that the orders to execute cattle came from the same people that many Africans suspected of being responsible for bringing rinderpest in the first place. Instead of seeing the recommendation as a neutral policy choice, it was taken as proof that colonists and colonial governments were making choices that would specifically damage African pastoralists. As a result, relations between colonists and Africans became even more strained. Furthermore, rinderpest's arrival in what is now Botswana in 1896 coincided with the Chamber of Mines reducing wages for miners by 30 percent while also lengthening work hours. This meant that many men not only lost their cattle wealth to the virus, but the alternatives were increasingly less able to provide an adequate standard of living.[20]

African cattle owners thus came to link rinderpest with malevolent intentions on the parts of white colonial officials. Colonial officials claimed to be helping the African herd owners, but their motivations were to protect white-owned herds. Further, their methods of protecting African-owned herds seemed to work *against* preventing the spread of the disease.

Rinderpest also had important environmental consequences. The demise of so many cattle during a single outbreak meant that there were not enough animals to graze on grasslands. Without cattle to keep the grasslands in check, thickets would develop. In these thickets, tsetse flies would thrive—and tsetse flies are responsible for sleeping sickness, or human African *trypanosomiasis*. This parasitic disease invades the central nervous system and causes death if not treated. Even if an infected person obtains treatment, any neurological effects, such as confusion, loss of coordination, and intense disruption of the sleep cycle, are irreversible. Thus, the loss of cattle due to rinderpest made it easier for sleeping sickness to spread.[25] Indeed, a major human African *trypanosomiasis* epidemic occurred in Uganda and the Congo Basin between 1896 and 1906[26]—precisely at the same time that rinderpest was beginning to devastate sub-Saharan Africa.

These events provide but a brief set of examples of how devastating rinderpest outbreaks have been throughout history. The disease decimated the European economy, facilitated colonialism in Africa, and spurred racial distrust among various groups. The disease also spurred the development of veterinary medicine and promoted the development of vaccinations for infectious diseases more generally.

One Health

Health and infectious disease have assumed a more prominent role on the global community's policy agenda in recent years. This has occurred for a number of reasons. First, the world has witnessed an increasing number of new and re-emergent infectious diseases. The emergence of SARS and AIDS, among others, has convinced public health officials around the world that medical science has not vanquished the microbial threat as once thought. Indeed, the Centers for Disease Control and Prevention report that at least 33 new infectious diseases emerged among humans during the last quarter of the twentieth century.[27] Significantly, most new infectious diseases in humans come from animal sources. At least 65 percent of major recent human infectious disease outbreaks have animal origins.[28] This includes a variety of influenza strains with avian or porcine origins, Rift Valley fever, and Ebola.[29] In addition to these new ailments, diseases once thought to largely be under control, such as cholera, tuberculosis, and malaria, infect increasing numbers of people every year and have mutated into more dangerous forms.

Second, governments increasingly recognize the potential political and economic consequences of diseases crossing borders. The SARS epidemic of 2002 and 2003 clearly demonstrated to governments the ease with which infectious diseases can enter new countries and the value of collaboration in preventing such a spread. On December 23, 2003, the U.S. Department of Agriculture announced the discovery of the first cases of *bovine spongiform encephalopathy* (BSE) in the United States. BSE, colloquially known as "mad cow disease," causes cattle to progressively lose motor control and eventually die. The disease can infect people if they eat beef from BSE-infected cattle. Among humans, the illness manifests itself as variant Creutzfeld-Jacob Disease (vCJD). vCJD causes catastrophic neurological damage and a severe decline in both mental capacity and motor function. As there exists no cure or treatment for vCJD, the inevitable end result is death. With the announcement of the discovery of BSE in the United States in 2003, 70 countries banned U.S. beef imports. U.S. beef exports dropped 83 percent in 2004, causing losses estimated at between $3.2 and $4.7 billion that year alone.[30] This economic loss all resulted from a single cow, and the effects on the United States were comparatively mild. Other countries that have experienced BSE outbreaks have faced even more severe consequences.

Third, a number of governments and international organizations have promoted the idea that health is a development issue. A country that wants to prosper economically, which would presumably benefit the entire international community, needs a healthy populace. Health is not an isolated issue, but rather an integral element of a grander international effort to spread prosperity. The United Nations' Millennium Development Goals place health at the center of efforts to alleviate poverty. Three primary goals—reducing child mortality; improving maternal health; and combating HIV/AIDS, malaria, and other diseases—explicitly and directly connect health and international development.[31]

Finally, the international community has started to take a broader view of who should be responsible for providing health care. No longer is health care solely the domain of the state. Nongovernmental organizations, international organizations, multinational corporations, non-state actors, and public-private partnerships all play significant roles in expanding health care infrastructures and providing services. This expansion reflects the recognition that these other entities can often better reach underserved communities and show the flexibility necessary to adapt to challenging circumstances.[32]

As the international community has paid more attention to health at the global level, there is increasing awareness that the concept of health itself must be broadened. The international community cannot adequately address human health without understanding the effects that the health of animals and ecosystems has on people. Infectious disease outbreaks in humans frequently arise initially in animal populations, and environmental and ecosystem changes may facilitate the ease of transmission of diseases from animal reservoirs to humans. The appreciation of the interconnectedness of human, animal, and ecosystem health has come to be known as One Health. The One Health Initiative, a collaborative effort of scientists, physicians, veterinarians, researchers, and professional organizations, has defined One Health as "the collaborative efforts of multiple disciplines working locally, nationally, and globally, to obtain optimal health for people, animals, and our environment." To that end, One Health's advocates emphasize the importance of controlling infectious diseases that "have helped shape the course of human history"—be they human or animal illnesses (p. 9).[33]

Recognizing the interconnectedness between human and animal health is simultaneously a very old and fairly new concept. Currier and Steele note that Hippocrates and Galen both drew on observations from animals and humans to formulate their ideas about health, and early physicians attended to both humans and animals.[34] Rudolf Virchow, the German doctor who is often credited as the father of modern pathology and one of the founders of social medicine, argued:

> Between animal and human medicine, there are no dividing lines—nor should there be. The object is different, but the experience obtained constitutes the basis of all medicine (p. 6).[35]

The divisions between animal and human health start developing in 1761 with the founding of the first school dedicated solely to veterinary medicine in Lyons, France—a development, as mentioned, spurred by outbreaks of rinderpest in Europe. By the early twentieth century, human medicine, veterinary medicine, and public health largely saw each other as distinct fields of study and research, and practitioners in each field did not necessarily draw on the insights of others.[34]

In the late twentieth century, new developments in human health forced scholars and practitioners to take stock of the connections between human, animal, and ecosystem health. Scientists realized that a large number of new infectious diseases were appearing in humans, and they traced their origins back to animals. The 1997 H5N1 influenza outbreak in Hong Kong arose from birds, and authorities culled 1.5 million birds in an attempt to stop the disease's spread.[36] The outbreak of West Nile virus in New York in 1999 puzzled medical and public health authorities until veterinarians at the Bronx Zoo connected the outbreak in humans with a simultaneous outbreak among birds.[37] The emergence of severe acute respiratory syndrome (SARS) in 2002 and 2003 has been variously linked to civets, bats, and other small mammals.[38] The Cambodian government struggled to balance human and animal health needs while remaining cognizant of international donors' wishes in the face of an H5N1 outbreak in that country in 2004.[39] These and other outbreaks of new and re-emergent infectious diseases spurred meetings and collaborative efforts among those concerned with human health, animal health, and environmental issues. These meetings eventually crystallized into One Health.[40] Karesh and Cook emphasized the importance of One Health when they noted that no single agency or international organization collected health information on both human and animals, but "diseases pay no regard to the divisions among species or academic disciplines" (p. 42).[41]

Through One Health, the international community has brought more attention to the necessity of understanding how human and animal health interact with each other in significant ways. This relationship can be direct, with animals acting as reservoirs for new human illnesses. Just as importantly, though, are the social and economic impacts of animal diseases on human societies. A disease like rinderpest does not cause illness among humans, but its outbreak can devastate a community or a country by undermining its economic, social, and political health. If a family loses its cattle to a rinderpest outbreak, it may lose its livelihood and sink into poverty. As a family's economic standing becomes more precarious, people may have less ability to obtain nutritious food or medical care, which in turn can have a negative effect on human health. Thus, a wholly animal disease can lead to poor human health. Appreciating these connections and actively working to prevent such negative outcomes is central to One Health's mission and emphasize its importance to the international community's conceptualization of health and health policy. The Global Rinderpest Eradication Program (GREP) is in many ways emblematic of the unique understanding of the connections between human and animal health.

Rinderpest eradication campaigns

To truly protect the international community, rinderpest could not simply be controlled; it needed to be eradicated from the face of the planet. So long as the virus remained present anywhere in the wild, it risked spreading across borders. A country that had eliminated the disease from within its borders could

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never be truly safe unless it engaged in a continual vaccination campaign year in and year out. *Eradication* means no infections, no presence of the disease in any host that potentially spreads infection, and no need for continued interventions to stop the disease's spread. Eradication is distinct from *elimination*, which stops new infections within a defined geographic territory but requires continual interventions to prevent the disease's reemergence; eradication also differs from *control*, which reduces the number of cases of a given disease to a manageable level with sustained prevention and treatment efforts.[42] Controlling or eliminating rinderpest risked missing some cattle and thus creating a weak link in a state's veterinary defenses, and it would have been incredibly costly. An eradication campaign requires higher upfront financial costs, but is less expensive in the long run.[43]

While some individual countries like the Soviet Union and China had eliminated rinderpest internally by the end of the 1950s, there had been no coordinated and effective international campaign to do so. The successful development of Plowright's vaccine made such an effort potentially feasible. In 1961, the Organization of African Unity convened a summit in Nigeria to begin a campaign to eliminate rinderpest from Africa. Joint Program 15 (JP15) sought to vaccinate all cattle in 22 African states (17 of which had rinderpest) in four, three-year cycles. The host governments supplied $7.2 million of JP15's total $16.4 million budget, with the European Development Fund, the United States, United Kingdom, Germany, and Canada supplying the rest.[44]

By 1979, most of Africa was rinderpest-free. Unfortunately, the program lacked extensive surveillance capabilities to keep tabs on where outbreaks were still occurring. More problematically, the early success lulled governments into a false sense of complacency, leading them to terminate their vaccination programs too early. As a result, the number of cases quickly rebounded, and the virus returned to many of the states from which it had previously been eliminated.[16]

Around the same time, major efforts began to eliminate rinderpest from Asia. In 1969, the disease broke out in Afghanistan and began sweeping westward. The Food and Agriculture Organization took the lead in conducting mass vaccination campaigns in all the states reporting cases of rinderpest, and it succeeded in eliminating the disease from all the targeted states except for Lebanon by 1972. Unfortunately, as was the case with JP15, seemingly quick success bred a sense of complacency. States neglected to conduct continued surveillance programs to ensure that the disease was truly gone, and some states lacked the basic veterinary capabilities to maintain and support the necessary therapeutic services for such an effort. During the early 1980s, rinderpest reemerged in Lebanon and spread from that country to Syria and Israel along with their troops as they departed after the First Lebanon War.[45]

The Indian government undertook large-scale national rinderpest elimination campaigns throughout the second half of the twentieth century. Its National Rinderpest Eradication Program (NREP) began in 1954. Under the program's aegis, in 1958 and 1959 alone the country vaccinated 26 million cattle. Success was quickly apparent. In 1956 and 1957, India recorded 8,000 outbreaks of rinderpest, killing 200,000 cattle. Within ten years, the number of outbreaks had plummeted to approximately 300 annually.[46] Despite this success, a failure to monitor the quality of vaccines and where vaccinations had occurred prevented NREP from eliminating the disease. One official lamented, "We had been vaccinating for more than 55 years and the number of vaccinations we had done was more than the world bovine population. But the disease was still there" (p. 991).[49] The failure diminished pressure on the government to eliminate rinderpest, and political support declined.

Recognizing that rinderpest was resurgent, national and regional elimination efforts ramped up during the 1980s. Leaders from across Africa met in Nairobi in 1982 to organize a new campaign after the end of JP15. They created the Pan-African Rinderpest Campaign (PARC), which began operations in 1986 in 34 countries. PARC took a unique approach to rinderpest elimination by integrating its operations with other vital services. In addition to conducting mass vaccination campaigns and providing disease surveillance systems, it also sought to expand access to veterinary services in general throughout the region and integrate its programs with larger concerns about fighting desertification.[47] By incorporating rinderpest elimination programs into other concerns, PARC's leaders hoped to generate greater public support and create programs that would persist even after the rinderpest campaign ended. India reinvigorated its rinderpest

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campaign in the 1990s through the National Project on Rinderpest Elimination (NPRE). Under NPRE, the European Union provided most of the initial supplies and vaccines, and the Indian government financed the project's operations. As with PARC, NPRE did not limit itself solely to rinderpest and instead used the campaign as part of a larger mission to improve veterinary services, disease surveillance capabilities, and training for local officials.[49]

These localized efforts helped, but they ran into substantial challenges. For one, they did not have the necessary financial resources to effectively carry out their missions. They also encountered resistance from herders, who feared that the vaccination would cause disease or attract cattle rustlers. Few vaccinators came from the affected communities, which undermined trust. Persistent conflicts made it difficult to reach some important pockets of disease. Perhaps most significantly, regional elimination efforts—even successful ones—are not the same as eradication. Elimination requires continual vigilance, surveillance, and vaccination because the possibility remains that rinderpest could inadvertently be reintroduced into an area from which it has been eliminated.[47] By the late 1990s, rinderpest was largely (though not exclusively) limited to southern Sudan, Ethiopia's Afar region, Uganda's Karamojong region, and the Somali rangelands. These areas all suffered from weak institutions, instability, and chronic conflicts, making it very difficult to conduct vaccination efforts and reach out to affected communities.[48] Efforts in Africa and Asia were useful, but could not achieve the ultimate goal on their own.

To fill this global void, the Food and Agriculture Organization (FAO) and World Organization for Animal Health (OIE) in 1994 announced the creation of the Global Rinderpest Eradication Program (GREP). GREP had three main missions: to coordinate rinderpest eradication efforts; to promote rinderpest eradication and raise the profile of such efforts; and, to provide support for vaccination and surveillance efforts. It would also provide verification for claims of elimination and eradication.[49] While spearheaded by FAO and OIE, GREP collaborated with the International Atomic Energy Agency, Africa Union, European Union, United States Agency for International Development, United Kingdom Department for International Development, national governments, local communities, and a range of nongovernmental organizations.[6] GREP did not necessarily replace national and regional rinderpest control programs; rather, it provided coordination and collaboration with them and encouraged the development of additional programs as needed.

GREP was unique in three key attributes. First, it was explicitly global in its orientation. It could facilitate fundraising, information sharing, and surveillance systems in ways that regionally or nationally oriented programs simply could not. In addition, its global mandate could give rinderpest and the efforts to eradicate it far more prominence than less ambitious programs could. GREP effectively put rinderpest back on the international agenda. Second, GREP set a deadline for its efforts. It set a deadline of 2010 for achieving verified global eradication. Previous national and regional efforts had largely been open-ended campaigns rather than time-limited programs. By setting an explicit deadline for itself, GREP sought to inject a degree of urgency into its efforts.[4] It also helped to combat donor fatigue by offering a definite timeline.[51] Third, GREP moved away from a top-down approach to vaccination efforts. Instead, it explicitly endeavored to empower and mobilize local communities. Rather than parachuting vaccinators from urban areas into local communities for a brief period before they depart, GREP encouraged the use of community-based animal health workers (CAHWs). CAHWs received basic training in animal health, disease surveillance, and vaccination, and they applied their skills toward rinderpest eradication as well as other local veterinary concerns.[48]

More significantly, though, CAHWs lived in the communities in which they worked. They knew the community, its practices and customs, and its history, which provided them a degree of credibility, trust, and support that had undermined the efficacy of previous efforts. Their detailed knowledge of their local communities also allowed them to be flexible and adjust their vaccination schedules as appropriate. Previous efforts lacked this sort of detailed knowledge and could not alter their plans to accommodate cattle migration patterns or unexpected events. Mariner and colleagues note that the CAHWs achieved a remarkable degree of success in the inhospitable environments in which they operated: "Community based vaccination programs thus achieved herd immunity levels greater than 80 percent and were at least as effective as

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the best public veterinary service programs in Africa conducted in more accessible areas" (p. 1310).[49]

The Global Rinderpest Eradication Program undertook a number of different activities on the ground to make progress toward total rinderpest eradication. The program undertook a massive epidemiological survey to understand where rinderpest was still active and map the lineages of the virus involved.[4] It worked with the Pan-African Program for the Control of Epizootics (PACE), the successor program to the Pan-African Rinderpest Campaign, to finally eliminate rinderpest from its remaining reservoirs in Africa.[47] To accomplish this, the eradication program developed and distributed technical guidelines to support eradication efforts; it supported the training of CAHWs; and it assisted with vaccination campaigns when asked, even stockpiling emergency vaccine supplies in the event of an outbreak.[50]

To verify whether the program was successful, GREP employed the World Organization for Animal Health's Rinderpest Pathway. Under the OIE Rinderpest Pathway, countries that were not rinderpest-free at GREP's inception had to (1) demonstrate a record of regular and prompt animal disease reporting; (2) submit a declaration to OIE that there had been no outbreaks of rinderpest for 24 months, no evidence of rinderpest infection for 24 months, and no vaccinations conducted during the past 24 months; and, (3) prove that it had not imported any animals vaccinated against rinderpest since the country halted its own vaccination program.[51] In order to meet these stringent criteria, a country would need to engage in and support extensive surveillance activities, keep timely and accurate records, maintain constant communication with GREP, reach out to any and all affected communities, and devote significant resources to veterinary health. GREP and the OIE Rinderpest Pathway did not necessarily specify the content of the programs that countries and regions used, but they did mandate the outcomes those programs should achieve.

GREP proved wildly successful. No Middle Eastern state reported a single case of rinderpest after 1997. By 2000, the virus was only present in three countries: Pakistan, Sudan, and Kenya. That year, Pakistan and Sudan recorded their last ever cases.[4] Tom Olaka, a community-based animal health worker (CAHW), identified the last known case of rinderpest in the wild. It was found in a buffalo in Kenya's Mount Meru National Park in 2001.[9] Five years later, after no new cases had been found, GREP ended its vaccination efforts, and FAO provisionally declared the world free of rinderpest. In 2009, GREP undertook extensive targeted surveillance exercises to confirm that no new cases had appeared and that no wild reservoirs remained. Finding none, FAO's director-general announced the end of GREP's field activities in October 2010 and awaited the receipt of the final country dossiers that would confirm that all states were free of rinderpest. All such reports were received by May 2011, and Chief Veterinary Officers meeting during the OIE World Assembly that month passed a resolution confirming the virus' disappearance from the wild.[51] Finally, on June 28, 2011, the 192 member states attending the FAO Conference adopted a resolution officially declaring global freedom from rinderpest. The resolution "declare[d] solemnly that the world has achieved freedom from rinderpest in its natural setting, one of the most dreadful animal diseases with severe impacts on livelihoods" (p. 1).[52]

Figuring out the cost of rinderpest eradication is remarkably difficult. All told, the United Nations estimates that the entire budget for rinderpest eradication from 1945 to 2011 totaled $5 billion. Dr. Peter Roeder, leader of GREP's final efforts, put this expense into perspective: "At first I thought, that's quite a lot. Then I thought, the last royal wedding cost $8 billion. This was cheap" (p. D1).[9] Another estimate pegs the figure for rinderpest eradication activities at $610 million between 1986 and 2008, with the expectation that completing final eradication verification procedures would cost an additional $10 to 12 million.[25] At no point did GREP put forward a unified budget with all the contributions and outlays in a single place. This is not a sign of disorganization or fraud; rather, many GREP-related projects were subsumed under more generic budget lines within FAO, such as promoting the privatization of veterinary services or strengthening local access to veterinary clinics. GREP's activities received funding from the regular FAO budget and programs within the agency, as well as the International Atomic Energy Agency, UNICEF, the United States Agency for International Development, the United Kingdom Department for International Development, the Swedish International Development Agency, the Irish government, and humanitarian aid efforts

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like the Iraqi Food for Oil Program and Operation Lifeline Sudan, among others.[53]

GREP's ultimate success is all the more remarkable because of how little faith leading veterinarians had in its chances. Sir Gordon R. Scott of the Center for Tropical Veterinary Medicine at the University of Edinburgh was one of the global leaders in international rinderpest eradication efforts in the second half of the twentieth century. In 1998, he wrote an article assessing GREP's chances, in which he gloomily concluded,

> The odds are stacked against global eradication of rinderpest. We can do little about wars and armed conflicts except pray for peace. Meantime we ought to seek acceptable and practical ways of preventing commercial traffic in rinderpest-infected animals. At present, the 'Nays' win the argument (p. 298).[15]

Despite spending his professional life to wipe out this single disease, or perhaps because of, Scott foresaw a future in which reducing the threat to the commercial cattle supply was the best the international community could hope to do. He believed that the persistence of civil and transborder conflicts would ultimately prevent eradication efforts from reaching all affected communities. Scott died in 2004[9]—seven years before rinderpest was declared eradicated, but three years after the last known wild case of the disease.

Lessons from rinderpest eradication

The experience of the successful global campaign to eradicate rinderpest offers the international community four important lessons for future eradication efforts. First, the right scientific and technical elements must be in place to facilitate eradication. This should be common sense, but it can be overlooked in the rush to wipe out a deadly pathogen. Without certain favorable scientific conditions, rinderpest eradication would have been far more difficult—if not impossible. The various rinderpest control programs could only achieve limited success until there existed a safe and reliable vaccine. Walter Plowright developed the first widely available vaccine in the 1950s, but even that was of limited use until the 1980s when a shelf-stable version was introduced. Without these scientific innovations, an eradication campaign simply was not feasible.

On the other side of the scientific ledger, the rinderpest virus itself has some unique characteristics that made it particularly amenable to eradication. A single type of vaccine works against all strains of the virus. Infected animals pass the virus directly to each other without needing an intermediary to facilitate transmission. The virus lacks other animal reservoirs, so its eradication from cattle and wild buffaloes effectively means that the virus exists nowhere in nature. These facts simplified the tasks facing the eradication campaign, since it reduced the virological targets that had to be addressed. Favorable scientific and technological factors are thus one crucial element that need to be in place before embarking on any disease eradication campaign. The failure to appreciate the importance of technological feasibility not only doomed malaria eradication efforts in the 1950s and 1960s, but inadvertently gave rise to more drug-resistant strains.[54]

Second, disease eradication campaigns are not solely about scientific and technological prowess. They must tap into and respond to the social, economic, and political contexts in which they find themselves. One of the biggest problems facing the rinderpest eradication campaign had nothing to do with vaccines or money; rather, it had to do with persistent violence and weak governance structures in the Somali Ecosystem of southeastern Ethiopia, northeastern Kenya, and Somalia. The uncertainty and challenges of this environment hampered vaccination and eradication efforts far more than any difficulties associated with transporting and injecting vaccines.

When previous rinderpest eradication efforts ignored local context, such as relying too heavily on outsiders to conduct the vaccinations, scheduling vaccinations at inappropriate times, and failing to understand the dynamics of pastoralist communities, they largely failed. The vaccinators reached too few people and cattle to be effective, and the disease continued to rage in these final outposts, such as Kenya and Somalia, because their efforts relied too much on a top-down approach. Success came when the eradication campaign turned to a more bottom-up approach that drew on local knowledge, expertise, and tradition to facilitate vaccination efforts. Success came when respected local residents were hired to serve as

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vaccinators, when vaccination campaigns were better timed, when fears about the potential for cattle-rustling were allayed, and when international aid agencies were able to work with combatants to arrange for temporary ceasefires in order to vaccinate. Even the most technologically sophisticated campaigns are meaningless without finding a way to work within local parameters. The underlying goals and desired outcomes of the campaign remained the same, but the techniques used in particular areas were able to accommodate local needs.

Third, rinderpest eradication worked because operations were integrated within other programs. Rinderpest eradication was not a standalone program with its own extensive budget, operational structures, and organizations. Instead, the effort fit its operations within existing programs. Much of the work of the rinderpest eradicators was part of larger campaigns to expand access to animal health services and promote veterinary medicine in rural areas. This community of animal health workers could provide rinderpest-related services, and their outreach was vital for increasing access to vaccination, but it was only one of a whole host of services that they offered. Pastoralists were certainly concerned about rinderpest, but it was not necessarily their top concern. Focusing efforts solely on rinderpest would not have attracted support from the communities that needed vaccination. Integrating rinderpest eradication into other animal health initiatives allowed the campaign to reach further than it might have otherwise.

Integration also allowed the rinderpest eradication campaign to operate on the cheap. It did not require a large budget, and it did not have to create a new organizational structure. Indeed, part of the reason that it is difficult to get a full accounting of GREP's overall budget is that so many of its activities and operations were part of other campaigns. Thus, it is impossible to wholly disentangle how much of a particular animal health campaign is related to rinderpest. The eradication program's unique organizational structure also changes the dynamics of political support from donor and recipient states. Donors were not asked for new and extraordinary outlays. Recipients were not asked to administer and monitor new programs. Rinderpest eradication may be an extraordinary and remarkable achievement, but it was positioned organizationally as just one more task being undertaken by existing international organizations. The effort's natural feel and integrative approach made it easier for donor and recipient governments to support.

Finally, the rinderpest eradication campaign provides empirical evidence for the value of embracing the One Health paradigm. Eradicating the disease was not done to alleviate suffering among cattle; it instead saw eradicating rinderpest as key to improving *human* health. The final, and ultimately successful, push toward rinderpest eradication drew its strength and inspiration from the interconnections between human and animal health. This validates the usefulness of One Health's integrative approach.

Interestingly, cattle vaccination campaigns like those used for rinderpest do have a direct and tangible benefit for human health when used in tandem with human inoculation efforts. Schelling and colleagues found that human vaccination rates significantly improved when human and animal vaccination campaigns occurred simultaneously. People who may not show up to get a vaccination for themselves would come to vaccination clinics when their animals could also be inoculated. These combined programs are less costly and benefit from shared logistics and outreach.[55] Fasina and colleagues found similar positive results in Nigeria. They argue, "By tying together human and animal health, improved public health results could be achieved in Africa" (p. 386).[29] These findings further reaffirm the efficacy of the One Health paradigm. Instead of seeing human and animal health as distinct realms, combining them together where appropriate leads to better health outcomes for both.

Many of these lessons are applicable to other disease control and eradication campaigns; rinderpest eradication was not simply the result of some lucky accidents. Technical feasibility is crucially important to any control or eradication campaign. It may be possible at some point in the future to eradicate influenza, but that is not possible in the foreseeable future. As such, pursuing an influenza eradication campaign is premature at the present. Eradication campaigns should draw on local knowledge and understandings in order to facilitate greater buy-in from the communities in which they operate. Health workers who speak the local language, understand the rhythms of life in the local community, and have engendered some measure of trust with the local population are more likely to be successful than those flown in from parts unknown. In most cases, local health workers can be trained to administer such campaigns. Disease control or eradication efforts need not always create new organizations or budgets; drawing on existing resources provides for greater efficiency, institutional support, and budgetary access. The ideas behind One Health apply to a wide array of disease control or eradication campaigns, be they targeted toward animals or humans. Planning, technical feasibility, and local awareness came together to ultimately make GREP ultimately successful, but there is little about these factors that is unique to GREP or rinderpest itself. Instead, these lessons should encourage other control or eradication campaigns to assess whether they can draw on the techniques and strategies identified here to make their efforts more effective.

Conclusion

The eradication of rinderpest is one of the most remarkable, yet least heralded, of global health accomplishments. Through the Global Rinderpest Eradication Program and its progenitors, the international community demonstrated it could come together and overcome serious obstacles to provide a global public good that has had a remarkable economic, political, and social payoff. There existed serious and seemingly insurmountable obstacles to successfully eradicating rinderpest, but the campaign's success offers important lessons for future disease eradication campaigns and the utility of the One Health paradigm recognizing connections between human and animal health. In particular, rinderpest eradication demonstrates the importance of having the proper scientific and technological prowess, fitting the campaign within the larger social, political, and economic context, integrating efforts within existing operations, and understanding the positive synergies that exist between human and animal health.

Rinderpest eradication shows that the global health community can achieve big goals when situated within the appropriate social, political, and economic contexts. Eradication campaigns will not succeed without scientific backing, but science and technology are not sufficient for campaigns to succeed. Context matters, and global health efforts will not succeed without acknowledging this fact.

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