11

Disease and Global Divergence

Successes and Failures in the Wonderful Century

In 1801, when he finished his term as president of the United States, John Adams magnanimously left his incoming rival Thomas Jefferson seven horses in the White House stables. Means of travel and communication had changed little since the days of Caesar (fittingly, the name of one of Adams's favorite horses). A century later, Adams's great-grandson Henry stood in Paris at the world's fair, the 1900 Paris Exposition, mesmerized by an electrical turbine, the "dynamo." Although he himself felt out of place in it, Henry lived in an age of steamships and trains, telegraphs and light bulbs. In the world of John Adams, medicine meant bloodletting and surgery that was little more than a gory gamble. Henry Adams, who narrowly survived the scarlet fever wave as a boy, lived to see anesthesia and antisepsis, the triumph of germ theory and the age of vaccines and pharmaceuticals.[1]

The nineteenth century is the crux of modernity. In 1899 Alfred Russel Wallace, the codiscoverer of evolution with Darwin, published *The Wonderful Century*, a reflection on the dazzling progress of the last hundred years, as well as a clear-eyed reckoning with its shortcomings and unfinished business. He concluded that "not only is our century superior to any that have gone before it, but that it may be best compared with the whole preceding historical period. It must therefore be held to constitute a new era of human progress." Yet, he soberly admitted, "this is only one side of the shield. Along with these marvellous Successes—perhaps in consequence of them—there have been equally striking Failures, some intellectual, but for the most part moral and social."[2]

Wallace counted thirteen innovations of the highest order: railways, steamships, telegraphs, telephones, matches, gas lights, electric lights, photographs, phonographs, X-rays, spectrum analysis to study the stars, anesthetics, and antiseptics. Set against this, he identified militarism, exploitation and humanitarian catastrophe in the colonies, the "plunder of the earth," the diseases and "insect enemies" that followed environmental degradation, and the squalor of the working class. The last was for Wallace an unforgiveable stain on the wonderful century: "the condition of the bulk of our workers, the shortness of their lives, the mortality among their children, and the awful condition of misery and vice under which millions are forced to live in the slums of all our great cities." Setting aside some lapses of judgment (Wallace championed phrenology and railed against vaccination), his balance sheet is remarkably broad-minded and perceptive.[3]

This is a chapter that is sometimes missing from big histories of both health and of economic growth, which either gloss over the setbacks of the nineteenth century or start after progress had resumed. In part this tendency is driven by a lack of good health data, especially globally, before the late nineteenth century. The most valiant effort to locate early sources of data was undertaken by James Riley, and it is evident from his findings that the statistical record for morbidity and mortality is hard to take back much further than 1900 for most of the world. But lack of data is not the only issue. There has also been a habit of treating infectious disease as a static and monolithic problem to be overcome, which ignores the negative consequences of growth and excludes the possibility that health conditions may actually have worsened.

We will try to work around some of these very real challenges. One way is to highlight the emergence of the most severe new disease in this period, cholera, whose radically different impacts around the globe are one proxy for the diverging patterns of health in the nineteenth century. Another is to bring plant and animal health into the discussion as a way of tracing some of the obviously negative ecological impacts of globalization. Finally, we can look closely at the case of India. Although obviously no country is representative of the entire developing world, there are reasonably good data for India from the 1880s. India bore the full brunt of the great pandemics of cholera, plague, and influenza. Old scourges like malaria became an even greater problem not despite but *because* of modernization. In consequence, life expectancy in India stagnated at best and probably declined.

The history of disease deserves to figure prominently in both the successes and failures of the nineteenth century. The paradox of progress is a common pattern in the human past: the material forces that enable population growth and human connectivity also create new ecologies of infectious disease and stimulate the emergence of new pathogens. This pattern played out on a grander scale than ever before. In the nineteenth-century context, there was a new twist: some human societies were gaining the ability to control infectious disease. This imbalance played out in fateful ways in a rapidly changing world. Germs have often worked to amplify, undermine, and shape differences between human societies. But now, for the first time, the relative ability to mitigate the impact of infectious disease became a major feature of global power dynamics.[4]

The global history of infectious disease in the nineteenth century is more than a story of successes and failures. It is about the counterintuitive and causal relationships between homogenization and divergence. The nineteenth century was a time of global homogenization in countless ways: Western dress, French culinary habits, German systems of ordering knowledge, Greenwich Mean Time, and much else besides. Fashions and ideas circulated faster than ever. So, too, did pathogens—pathogens of humans and, as we will see, of plants and animals as well. It is telling that the very word "pandemic," in the sense of a global-scale outbreak of infectious disease, came into currency over the course of the nineteenth century. Not only were such events more likely to happen than ever before; human observers could also perceive and talk about and respond to them in ways that were impossible prior to modern communication and transport.[5]

The flip side of homogenization was divergence. What economic historians call "the Great Divergence" refers to the dramatic gaps that arose between the West and the "rest" in this period. Divergence is often measured in terms of power or money. By the time of World War I, Europe and its offshoots had commandeered most of the land surface of the planet. Meanwhile, differences in standards of living also widened. Ordinary laborers in western Europe and the United States came to enjoy per capita incomes ten times greater than those of their counterparts elsewhere. Although the issue has received far less attention, these gaps are paralleled in the history of health and infectious disease. Global divergence in life expectancy peaked in the early twentieth century before starting to converge again.[6]

We should emphasize that, even in the most economically and scientifically developed societies, the "wonderful century" did not bring unbroken progress, and the triumphs of modern medicine hardly seemed foreordained. For a time, urbanization, industrialization, and globalization outran advances in science and public health. By the 1860s, improvements in life expectancy had actually stalled or regressed in much of western Europe. In Britain, the pacesetter of industrial transformation, the achievements of the previous decades appeared tenuous, and science seemed impotent in the face of nature's whims. In 1865, with a gruesome cattle plague raging and a global cholera outbreak knocking at the door, one English churchman crowed that disease had humbled modernity: "All the medical men, all the learned men and philosophers, and all the practical men, and all the farmers, are puzzling and perplexing themselves about it, yet they cannot find out the cause of it. . . . It baffles their skill!"[7]

With hindsight, we know that he was wrong. Cattle plague was quickly controlled in Britain, while the cholera pandemic sweeping the planet was kept out. But in many places the confrontation with an ever more integrated global disease pool proved overwhelming. In the late nineteenth century, cholera killed tens of millions in British India. The cattle plague brought fresh misery to Africa. In short, the divergence in incomes and power was inseparable from the diverging experience of infectious disease around the globe.

The Global Context of Modernization

In 1798, when Malthus published the first edition of his essay, there were a billion people on the planet, give or take. By 1900, there were 1.6 billion humans alive. And while stagnation ruled over vast parts of the earth, industrial societies had started to make the Great Escape from hunger and premature death. Industrialization brought massive productivity increases and per capita economic growth in western Europe, the United States, and Japan. Elsewhere, per capita income remained low. In the early nineteenth century, the gap in per capita income between western Europe and the United States, on the one hand, and the rest of the world, on the other, was maybe two to one or three to one. In 1820, annual per capita income in China—one of the most advanced regions of the global economy outside Europe and its offshoots—was $624 in modern terms. In France, it was $1,442. By 1900, China had moved only a little ($840 per person, per year), and most of the tropical world still endured incomes near the subsistence level (Peru at $604, Brazil at $606, Indonesia at $1,076). Incomes in France had reached $4,214 per capita, Germany $4,596, and the United Kingdom $5,608. Although precision is specious, the overall pattern is clear enough. A yawning gap had opened.[8]

Modern growth had started with the application of coal-fired steam power to machines in mining and textile production. In the nineteenth century, the range of applications widened, as manufacturing and eventually transportation were transformed by fossil energy. Both technical innovation and the use of fossil fuels expanded to become systemic. The geographic scope of the industrializing world simultaneously grew. Although England was the early leader, other western European countries and the United States rapidly followed in the early nineteenth century.[9]

Innovation was reinforced by expanding markets and the rise of mass education. Schooling became compulsory in the industrialized world, and the public provision of education was enlarged, providing a massive boost to human capital. Basic scientific discovery accelerated, and knowledge of the natural world in turn created innovation and wealth.

By the 1880s, these changes catalyzed what is known as the Second Industrial Revolution, a great burst of new innovations driven by big steel, electricity, hydrocarbons, the internal combustion engine, and industrial chemistry. This new generation of technical marvels, put on display in Paris in 1900, is what so impressed Henry Adams as a rupture with all of previous human history.[10]

The innovations of the nineteenth century would have amounted to little without the energy to fuel them. In 1800, 70 percent of mechanical energy used globally came from human muscle. Power was thus fundamentally constrained by the physical limits of the human body. With industrialization, it became possible to convert fossilized solar energy to mechanical power. Already by 1800, steam engines could achieve 20 kilowatts of power. Over the course of the next century, that capacity increased thirtyfold, and engines became relentlessly more efficient. World production of coal exploded. The possibilities of petroleum were discovered in the 1850s, and from the 1880s oil gained practical importance with the development of the internal combustion engine. By 1900, mineral energy had passed biomass energy as a source for global energy use.[11]

From the very beginnings of industrialization, anxieties about resource exhaustion coexisted with blustery promises of infinite growth. Humans had been pushing remorselessly against limits for centuries—felling forests, hunting and fishing to extinction, strip-mining the earth, depleting soils, and expanding frontiers. In the 1780s, British mining engineers were already worried about "peak coal." But breakaway growth in the nineteenth century inspired new visions of cornucopian plenty: limitless growth, the substitutability of scarce resources, the power of human ingenuity to overcome ecological constraints. The great world's fairs of the age were an expression of this confidence and helped to cement it in the public mind. But this exuberant optimism should not obscure the fact that modern growth was, and still is, predicated on the use of finite resources—what Wallace evocatively called "the plunder of the earth."[12]

Over the course of the nineteenth century, behind machine-driven growth, the weight of global population shifted to the west. The Asian share of global population fell from two-thirds to a little over half, while

TABLE 11.1. Annual Growth Rates by Period and Region

	1500–1820	1820–70	1870–1913
Western Europe	0.26	0.69	0.77
Russia	0.37	0.97	1.33
United States	0.5	2.83	2.08
Latin America	0.07	1.26	1.63
India	0.2	0.38	0.43
Japan	0.22	0.21	0.95
China	0.41	−0.12	0.47

Europe, Russia, and the Americas grew from about a fifth to a third. Growth rates in the United States were stupendous, thanks to frontier expansion and mass-scale immigration, but even in western Europe, growth rates doubled or tripled, which makes the per capita income growth even more remarkable (see table 11.1).[13]

Population expansion in Europe and the United States was achieved, in part, by avoiding major cataclysms; the century between the Napoleonic Wars and World War I was a period of relative internal peace in Europe. Food production, complemented by food importation, kept up with demographic increase, in defiance of persistent Malthusian concerns. The exception that proves the rule is the Great Famine in Ireland, which was "*the* disaster of the century in Europe." Otherwise, such unmitigated humanitarian catastrophes were conspicuously absent. Cholera, as we will see, threatened to spiral into a calamity, but by tremendous exertions of effort it was mostly kept under control in Europe and the United States.[14]

By contrast, nearly everywhere outside of Europe and its settler offshoots experienced crises of enormous magnitude in the course of the century. The most dramatic instance is China, whose population actually contracted in the mid-nineteenth century. The eighteenth century had been prosperous and remarkably stable under Qing rule. But this stability was interrupted from around 1850 by a sequence of revolts and famines. The death tolls from these crises are staggering. Numbers can be taken with a grain of salt, but the Taiping Rebellion (1850–64)—an anti-Manchu uprising, with millenarian elements—may have claimed thirty million lives in the fertile southeastern provinces and in much of the Yangzi valley. The Nian Rebellion (1851–68) was a peasant revolt in the north that also brought devastation. The Chinese empire threatened to come unbundled with Muslim revolts in both the northwest and southwest (the Dungan and Panthay Rebellions) seeking liberation from the Qing state. And in the 1870s and 1890s, terrific famines swept the country. The Great North China Famine of the late 1870s put some ten million victims in their graves.[15]

The Chinese disasters of the nineteenth century were a dynastic crisis of the Qing. They were simultaneously crises of Chinese imperialism, with tensions flaring in quasi-autonomous frontier regions. It is also necessary to see these upheavals as Malthusian-ecological crises. China's population had grown from 150 million to 300 million between 1700 and 1800, and then by another 150 million over the next fifty years. Potatoes and other New World crops fed this expansion, but there was no transition to sustained technology-led growth. Demographic pressures set the stage for mass-scale violence. Changes in the global order exacerbated problems. Even as European power expanded globally, China was never colonized. Instead, western powers demanded access to trade. The British, in particular, coveted tea, and wished to pay for it with opium produced by their Indian colonies. Objections by the Chinese state were forcefully overridden in the two Opium Wars (1839–42 and 1856–60). These conflicts made apparent the military chasm that had opened up between East and West, embarrassed the Qing rulers, and worsened the problem of narcotics addiction.[16]

India's population history sits somewhere between the Chinese and European examples, and here colonialism was a primary factor. India achieved slow and modest demographic growth, despite a series of major famines in the late eighteenth and late nineteenth century. These were humanitarian catastrophes on the biggest scale, with tens of millions perishing. The famines in India were front of mind for Wallace as an indictment of modern progress. Moreover, as we will see, the globalization of infectious disease hit India especially hard.[17]

In Australia and much of the Pacific, the demographic trajectory of the nineteenth century was in some ways a replay of the Columbian

Exchange. Contact with relatively remote islands introduced novel pathogens to native populations. The indigenous inhabitants of Tahiti, Fiji, and New Caledonia suffered severe demographic losses. The story of Hawaiʻi is illustrative and well documented. When Captain Cook arrived in 1778, he ended a long period of isolation. The islands were home to more than half a million people. Westerners introduced syphilis and gonorrhea, and in the following years came typhoid, dysentery, whooping cough, measles, and smallpox. The tragedy played out in miniature in 1824, when a royal delegation from the island including King Kamehameha II and Queen Kamamalu traveled to London on a whaler to seek a British alliance; they were received with polite fascination in England, but within a month measles struck the royal party. Both the king and queen died. The lopsided disease exchange meant that within a century of European contact, the indigenous population of Hawaiʻi declined by more than 90 percent.[18]

Africa's population history in the nineteenth century remains obscure. The decline of the slave trade, first in West Africa and then in the eastern half of the continent, might have cleared the path to new growth. But it seems that there was stasis. By 1900, the continent was home to around 150 million people, not far above what it had been a century before. The burden of infectious disease kept mortality rates high. And the already hazardous disease ecology only became worse as the continent was more deeply integrated into global trading networks. The introduction of cholera was lethal, and old germs, like smallpox, were repeatedly reintroduced to the continent. The "scramble for Africa," the sudden onset of direct colonization, brought new forms of exploitation and violence. Among the worst effects of modern globalization was the introduction of unfamiliar veterinary diseases, the rinderpest virus above all. The decades immediately following colonization were an "epidemiological disaster for Africa." In all, "the stasis and even decline in African populations of the nineteenth century suggest that a combination of global conditions and domestic crises were constraining Africa in this era of imperialism and industrialization."[19]

Globally, besides the sheer multiplication of human numbers, there were also profound transformations in the spatial ordering of human populations. Virtually everywhere on earth, human populations became simultaneously more dense, more mobile, and more interconnected. These changes were pushed by industrialization and new technologies of transportation and communication, but they also transcended purely material stimuli. The rise of the modern city is a phenomenon in its own right, and one with many consequences for human disease.[20]

Cities grew larger, and in industrializing societies the proportion of the population living in a town increased dramatically, particularly from about the 1870s. Transportation systems enabled urban growth and linked towns into networks of production, distribution, and finance. It was the golden age of the port city, and railroads gave rise to the "junction." Growth was most spectacular at the intersection of industrialization, frontier expansion, and transportation hubs. Chicago embodied these changes in exaggerated form: a city of thirty thousand at midcentury, it was home to 1.1 million residents only four decades later.[21]

Cross-currents of health and disease coursed underneath the rise of the modern city. As we saw, the timeless role of cities as demographic sinks started to change in the eighteenth century, behind the early health transition. In some European towns, birth rates surpassed death rates, allowing natural increase. However, in 1800, there was still an urban penalty, and the countryside remained far healthier than the city. In the early stages of urbanization, national-level life expectancies actually declined as the weight of populations shifted toward the city. But in the latter half of the century, improvements accelerated in the developed world. By the early twentieth century, urban populations were healthier than their rural counterparts, a pattern that endures.[22]

Urbanization represented a kind of internal mobility. But long-distance migration was also a form of mobility accentuated by changes in the nineteenth century. In the words of the historian Jürgen Osterhammel, "No other epoch in history was an age of long-distance migration on such a massive scale." In the century before World War I, more than eighty million people migrated from one country to another. There were three main flows. The first was the "settler revolution," the push of populations into conquered regions, mainly in temperate climates. This

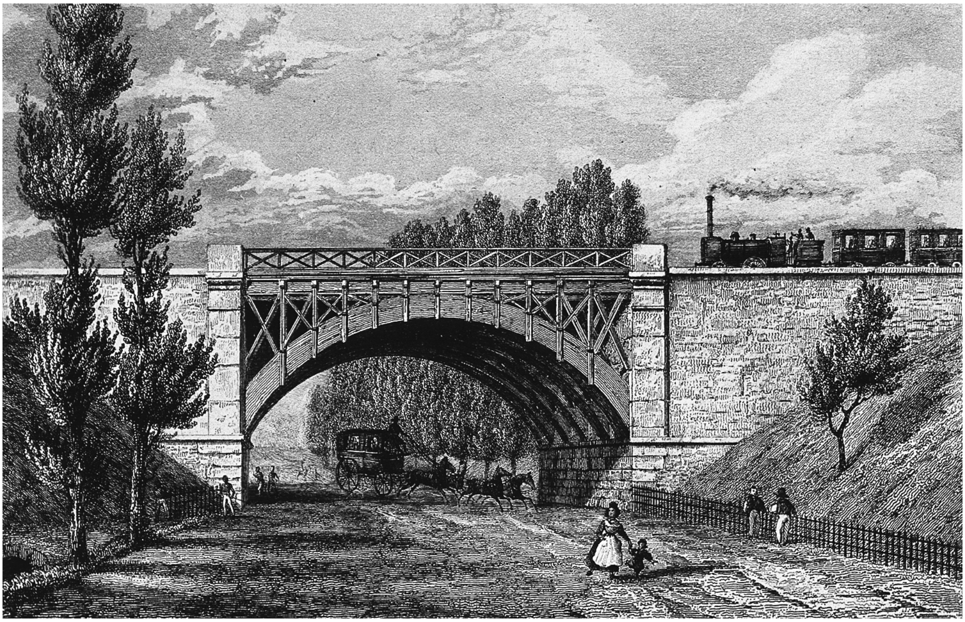

FIGURE 11.1. Age of Steam, Nanterre, France. Engraving by Charles Rauch. In the nineteenth century, steamships and railroads started to replace horse-, wind-, and human-powered transportation. Wellcome Collection (CC BY 4.0).

was mostly an Anglo phenomenon in Canada, the United States, and Australia, but it had analogues in Russia and China. The second was the transition from the slave trade to contract labor. Indian and Chinese "coolies" were pulled by the millions into the tropics and the American west. The third was the magnetic attraction of the United States for European migrants. Novel in their scale, these migrations continued many of the processes set in motion in previous centuries, including the long tragedy of indigenous dispossession. The swashbuckling "land runs" of Oklahoma, for instance, carved up remaining pieces of Indian Territory for settlement at the end of the century.[23]

Human movement was driven in part by the revolution in transportation (see figure 11.1). In *The Wonderful Century*, Wallace put transportation technologies at the head of his list of life-changing innovations. The steamship and the railroad were arguably the most transformational technologies of the century. Before the nineteenth century, the most advanced modes of transportation depended on wind power or horses. Both imposed considerable constraints on the volume and speed of movement that had changed little over the millennia. Napoleon's army deployed to Egypt in 1798 no faster than a Roman army could have; two decades later, when the *Savannah* became the first steamship to cross the Atlantic, there were worries it would be dispatched to Saint Helena, the remote island where Napoleon had been exiled, to bring him to Europe.[24]

The impact of the steamship was first felt along rivers and canals, and soon ocean voyages were possible. In 1828, the governor-general of India arrived in Calcutta by steamship to great fanfare. Steamers were outfitted with heavy artillery, and the spectacular defeat of China in the Opium Wars was decided by gunboats. The opening of the Suez Canal in 1869 knocked four thousand miles off the voyage from Europe to Asia. Steamships grew in size, number, and fuel efficiency, and by century's end, nearly all steamships in service were made of steel. The railroad accomplished an analogous revolution on land. The 1840s "were a time of railroad fever in the Western world." The golden spike joining the eastern and western rail networks of the United States was hammered in 1869, and transcontinental networks connected most of the Old World; by 1910, "with only one short interruption to switch gauges, people could travel by train all the way from Lisbon to Beijing." Rail construction was integral to colonial projects, most notably in India, where it was vastly more efficient than riverine transport. Railroads allowed humans to impose transportation grids that effaced natural constraints and obstacles. Tellingly, railroad schedules also played an important role in the standardization of time.[25]

The transport revolution quickened the pace of global trade and altered its character. Before the nineteenth century, most long-distance trade carried high-value commodities, usually goods that could not be produced or supplied locally, such as tropical groceries. But as freight costs plunged, it became economical to ship bulk goods. Basic foodstuffs came to occupy a much larger share of trade. The British Empire promoted free trade, and in real terms of value, global trade increased tenfold between 1840 and the eve of World War I. Prices were increasingly coordinated by global markets, and capital flowed from centers of finance to investments worldwide. Very often, this meant that capital from Europe secured ownership over raw materials or natural resources vital to production, like minerals or plantation goods, as supply chains became more complex. The growth of trade also marks a point of inflection in the history of disease. Trade surpassed war as the greater force in the transmission of contagious disease. More often than not, the outbreaks of the nineteenth century came in peace.[26]

Fuel-powered transportation was a watershed. It forever broke what the historian Braudel called the "tyranny of distance." Not since the domestication of the horse had there been innovations in the means of transport with such radical implications for the transmission of disease. The triumph of steamships and railroads marked a new epoch in the long history of globalization, one that was only left behind by the rise of jet travel in the late twentieth century.

The Age of Pandemics

The globalization of disease in the nineteenth century gave the word *pandemic* its current meaning. Despite its Greek roots (meaning "all" and "the people"), *pandemic* only came into usage as a medical term in the early modern period. For centuries, it was synonymous with *epidemic*, and meant simply a disease outbreak. In the 1828 edition of Noah Webster's dictionary, for example, a pandemic is still defined as an epidemic. Over the course of the century, the word *pandemic* came to be reserved for epidemics of interregional scope, for planetary waves of infectious disease. The evolution of the word reflected both reality and perception. Diseases like cholera and influenza rippled out across the earth in widening circles with startling speed. Scientific and political interest in global public health was increasing. Mass media and telecommunications made it easier to track global-scale disease events in real time.[27]

The transformations of the nineteenth century created a global disease ecology. The density, mobility, and connectivity of human populations played to the advantage of our parasites. Cholera was the quintessential emerging disease of the nineteenth century. It could both travel

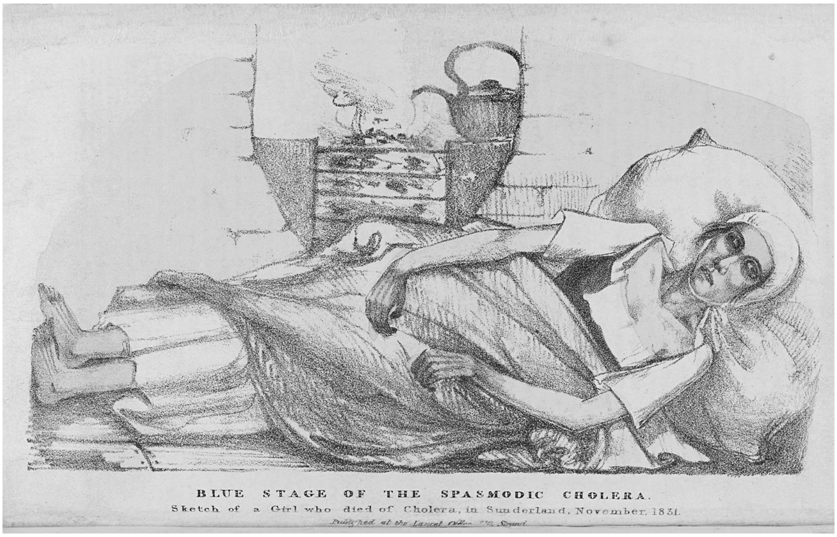

FIGURE 11.2. Cholera in Sunderland, England, in *The Lancet*, 1831. Wellcome Collection (CC BY 4.0).

quickly and take hold tenaciously. But long-familiar epidemic threats like yellow fever, influenza, and bubonic plague circulated farther and faster than ever before on global networks. And endemic diseases such as malaria also cast a pall over modern growth. Although less spectacular, these ancient scourges were destructive of human life and became more important than ever in the modern age. Genomic evidence is now enriching our understanding of the "homogenization" of human diseases that were already globally dispersed. Traces of European expansion are reflected in the spread of more virulent lineages of TB, for instance, which "'swamped' pre-existing local indigenous strains."[28]

Let us consider cholera as an exemplar of new ecologies of disease and disparate social responses. It is hardly original to treat cholera as the germ of the century and a symbol of its paradoxes. Cholera, a bacterial disease transmitted via fecal contamination of water, was not the most deadly affliction of the nineteenth century. But it was the most feared, at least in the West, where its appearance threatened the tenuous control over epidemic mortality that had so recently been won (see figure 11.2).

In the words of historian Christopher Hamlin, cholera "grew up in conjunction with Enlightenment liberalism, nationalism, imperialism, and the rise of global biomedical science. It was most problematic—as opposed to causing the greatest mortality—in precisely the places where these darlings thrived." Western societies managed to bring the threat of cholera under control, yet globally, the cholera pandemics of the nineteenth century carried tens of millions into their graves.[29]

Cholera is a disease caused by a comma-shaped bacterium, *Vibrio cholera*. The word *cholera* had been used as a medical term to describe gastroenteritis for centuries (reflecting its roots in ancient humoral theory: *choler* is the word for yellow bile). In the nineteenth century, the name was lent to describe a new disease that exploded into a series of global pandemics. The first cholera pandemic is conventionally dated to an outbreak that erupted in 1817. Successive waves of disease seemed to emanate from South Asia, and the new disease was sometimes called "Asiatic cholera" to distinguish it from more benign diarrhea and vomiting. Some medical writers even started referring to *cholera nostra*, or *our* cholera, to specify the generic diarrheal disease of old. The new cholera was something altogether more dangerous.[30]

There have been seven global pandemics of cholera since 1817. In reality, we should imagine these pandemics as pulses of disease diffusion, followed by long-lasting establishment of the bacterium in many regions. Tree thinking and time travel have confirmed that all of these pandemics were caused by a single lineage sharing a common ancestor only a few hundred years ago. Thus, it was only recently that the cholera bacterium acquired the necessary adaptions allowing it to be an effective human pathogen. Crucially, *V. cholera* evolved the ability to know from chemical cues when it is in the human gut. When it senses that it is in this environment, it activates virulence genes that not only make us very sick but also guarantee the massive expulsion of watery diarrhea that supports its transmission in human populations.[31]

The chain of evolutionary events that led to modern human-adapted *V. cholera* probably happened in the Ganges Delta (see figure 11.3). The Ganges Delta is the world's largest delta, today home to more than one

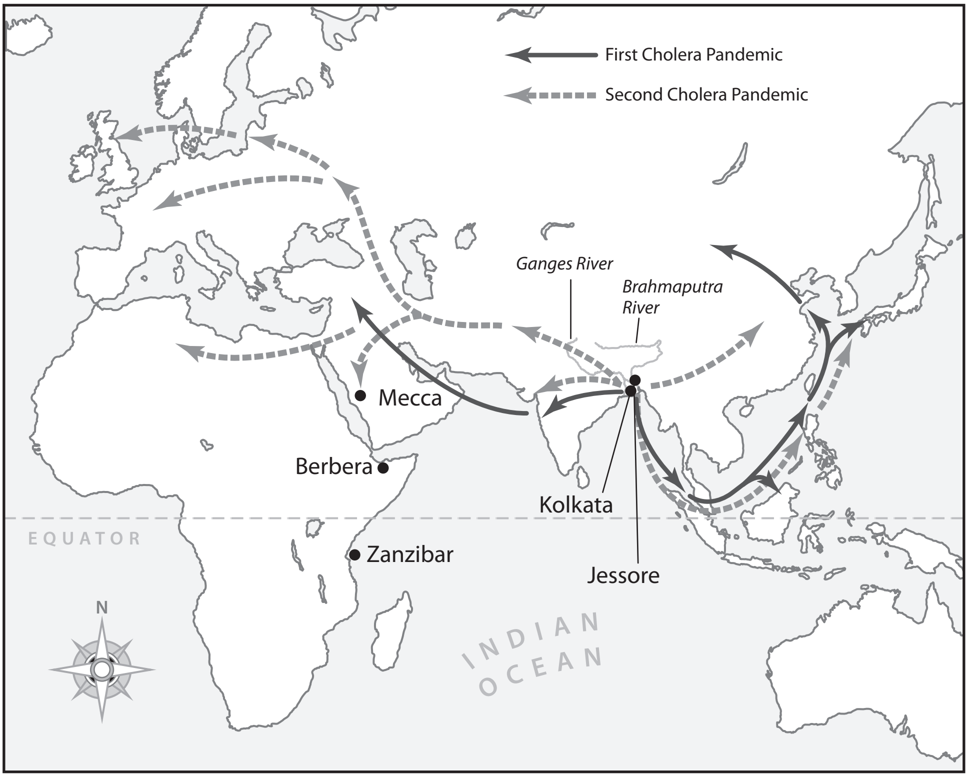

FIGURE 11.3. Cholera helped create the modern understanding of "pandemics" as planetary-scale disease events.

hundred million people. It has the climate and landscape to concentrate human beings in an ecosystem where *V. cholera* is rife. The Ganges River is sacred in Hinduism. Over the centuries, as people drank its slightly saline water, or bathed in its cool stream, they ingested the bacteria, and those bacteria that had the genetic makeup to multiply explosively in the human body and eject prolifically into the water supply were an evolutionary success. The Ganges Delta would prove to be the epicenter of the global pandemics and a stable reservoir between pandemics. It is likely the evolutionary birthplace of the pathogen.[32]

The outstanding feature of infection with pathogenic *V. cholera* is the loss of fluids. The bacterium enters the body via the mouth in contaminated food or water. The incubation period ranges from a few hours to a few days. Some patients suffer a mild disease, with modest amounts

TABLE 11.2. Chronology of Seven Global Cholera Pandemics

First	1817–24
Second	1829–51
Third	1852–59
Fourth	1860–75
Fifth	1881–95
Sixth	1899–1923
Seventh	1960–present

of loose stool. Most, however, experience a fast and furious battle in the bowels. The first symptoms are vomiting and watery diarrhea. There is no mistaking the "truly amazing copiousness of these evacuations." The diarrhea continues even after the bowels are empty, ejecting a clear fluid often called "rice-water stool." As the tissues under the skin are drained of fluid, the skin loses turgidity. The patient turns bluish, and the body appears sunken. The loss of salt and water is so sudden and severe that many patients die within a day.[33]

Cholera might not have been entirely new in the nineteenth century. It is possible that the bacterium had occasionally diffused before the start of the modern pandemic era. The molecular clock analysis does suggest that pathogenic cholera has been adapting to humans for a few hundred years. A series of outbreaks attested in India from the 1760s is especially likely to have been the prelude to the first pandemic. But the outbreak of 1817 marked the beginning of a new era in the history of the disease, both in perception and reality (see table 11.2).[34]

By August 1817, following unusually heavy rains, an outbreak was in progress near Jessore, a town in the Ganges Delta. Jessore is about fifty miles from Calcutta (modern Kolkata), the capital of British India, where escalating mortality startled the imperial authorities. Over the next three years, the disease affected most of India. It spread outward overland through South Asia. It also moved by sea, curling to the east, where it reached Indonesia, China, and Japan, as well as to the west, sprawling over the Middle East. The first pandemic touched the edges of eastern Europe but failed to penetrate farther. Similarly, it reached the coast of East Africa but spared the interior.[35]

The arrival of global cholera was a conjuncture of natural and human history. A bacterium that normally clings to crustacean shells had learned to invade the human gut. But this was not sufficient to spark the global health disasters that ensued from 1817. Colonialism and capitalism were necessary for that. Calcutta in particular was in the throes of rapid urbanization. The Ganges Delta sat at the nexus of British commerce in the east and was a global hub. Following the victory over Napoleon in 1815, the British Empire was ascendant, and its active promotion of international trade, now amplified by new transportation technologies, created the great expansion of global commerce that lies behind the cholera pandemics.[36]

The second (1829–51) and third (1852–59) pandemics were vast in their geographic reach. They were by far the deadliest outbreaks in Europe and the United States. In the industrial world, the cholera pandemics struck along class lines, devastating the slums where the working poor were concentrated. Because the cholera bacterium spreads via the fecal-oral route, it thrives on squalor. But the overlap between the risk of contracting the disease and social stratification was always imperfect: at any time, the germ might find its way through runoff or soil to the drinking water of the affluent. Cholera was thus quickly entangled with concern for, and fear of, the poor. Consequently, the cholera epidemics in Europe helped to galvanize the public health movement and strengthen its calls for sanitary reform, even as the nature of the disease and the value of quarantine were hotly debated for decades.[37]

Over the course of the nineteenth century, the differences *between* societies in the ability to withstand cholera became sharpened. In Europe and the United States, the fourth (1860–75), fifth (1881–95), and sixth (1899–1923) pandemics were either kept out or quickly contained. Where cholera did strike, it was a scandalous exception, as in Hamburg in 1892. But globally, cholera continued its devastating career.[38]

The patterns of global divergence in the course of the cholera pandemics can be starkly illustrated by the course of the fourth pandemic on the island of Zanzibar in 1869. Zanzibar is an archipelago of small islands off the coast of Tanzania. It offers ready access to interior Africa and has been a node for exchange since ancient times. It was a global meeting place, where Indian and Arab traders rubbed shoulders with Africans and Europeans. Zanzibar was the most important entrepôt in the eastern slave trade, a fact that made it of special interest to the British, whose gunships patrolled the coasts trying to suppress the trade. The islands also boast some of the finest clove plantations anywhere in the world. In the 1860s Zanzibar was controlled by the sultan of Oman, whose sovereignty was underwritten by British naval power. The gathering forces of globalization were refracted through this busy hub.[39]

We can follow the course of the outbreak on Zanzibar in unusual detail through the eyes of Dr. James Christie. Christie was a Scotsman educated at Glasgow, and from 1865 to 1874 he served as the personal physician to His Highness the sultan of Zanzibar. Christie was a sharp-eyed observer with a sensitive understanding of the Zanzibari milieu. Christie's studies of the outbreak, first in a series of reports published in the medical journal *The Lancet*, then more expansively as a book, *Cholera Epidemics in East Africa*, are a vivid chronicle of the deadly disease. The themes that Christie explored were of urgent interest, not least because the Suez Canal had been opened in 1869, the very year the outbreak reached Zanzibar. Europe had drawn closer to the Indian Ocean than ever before.[40]

The fourth pandemic had arrived in Mecca by 1865. Pilgrimages had become major conduits for global disease transmission, and from Mecca, the outbreak crossed the Red Sea and arrived at the great trading center of Berbera on the Somali coast. Berbera was "one of the oldest trading localities in the world," where caravans from interior Africa met to exchange with merchants on the coast. Cholera diffused inland along the arteries of Africa, infecting the Masai country dominated by powerful tribes of herders. The mortality was "appalling." Christie believed that the disease had spread overland and then curled back to the shores of East Africa. From there, in December 1869, the disease jumped to the island.[41]

The city of Zanzibar lacked sanitary infrastructure. "There are no sewers for carrying off the water from the place, and all the filth and rubbish of the town is swept to the beach by the street torrents." Cesspits were ubiquitous, plumbed into the soft, sandy soil. "The latrinae, which are in connection with every house . . . are merely shallow pits or wells, and the contents are not discharged by sewers to the sea-beach. . . . The fluid contents percolate the porous soil, and gradually find their way to the adjacent shore. When the latrinae become blocked up with the accumulations of a generation or two, as the case may be, they are either closed up and new ones excavated, or the slimy, semi-solid contents, are baled out on the public streets, and left to find their way by the nearest slope towards the sea-beach." The town was crawling with vermin. "Countless myriads of ants and beetles, millions of rats, and armies of wild dogs, aid in removing the garbage of the town and suburbs." The stench of the beach was also legendary.[42]

Christie understood that the water supply was essential to the epidemiology of cholera. He also recognized that ethnic segregation on the island, accentuated by social and cultural differences, shaped the course of the outbreak. The epidemic first ravaged the poor quarter of the town, and there were reports of slaves "suddenly ill at their work . . . staggering home to die." Early in December, as the fast of Ramadan began, the outbreak spread. Christie treated his first case, an enslaved girl. He described "a peculiar coldness . . . a cold clamminess of death, which, when once felt, can never be forgotten." His patient suffered intense thirst, and her pulse weakened. "The skin of the fingers, toes, hands, and feet became shrivelled; the features pinched; the eyes sunken, and glaring; and the entire aspect of the countenance changed." Like many cholera victims, she sank toward death with lucidity. Her "intellectual faculties were clear to the last."[43]

As the contagion spread, a gloom fell over the city. Yet no one tried to flee, and Christie was struck by the charity that everyone showed to members of their own community. At first bodies were at least wrapped in mats and dragged with a pole to the outskirts of town, where they were put in shallow graves. But gradually all customs were overwhelmed. "At last, tired of scooping out even the shallow graves, they began to expose the dead on the sea-beach, and to throw them over the bridge into the sea." Christie noted that the spread of the epidemic to the plantations was erratic, because only some of the outlying villages became infected by laborers who came into the city. Christie was also keenly interested in the variable fate of ships in the harbor, which often drew their water from the unsanitary wells along the shore. Several American ships called during the pandemic, but the two that hurried off were spared any deaths. In all, the mortality was both severe and lopsided. Nineteen Europeans and Americans died on ships. But not one of the resident westerners, all of whom had access to clean water, fell to the disease. The Hindu population, too, was spared. But the mass of destitute men, women, and children on the island, who did not have access to clean water, were unable to escape. By the end, Christie estimated that twelve to fifteen thousand residents of the city had died, out of a population of eighty to one hundred thousand. On the entire island, with a population of three hundred to four hundred thousand, some twenty-five to thirty thousand perished.[44]

What happened on Zanzibar is thus a microcosm of the nineteenth century. The 1860s were a turning point in the global history of cholera. Thereafter, the germ was almost entirely absent from western Europe and its offshoots. By contrast, it continued to produce grisly death tolls in regions where it found poor and crowded populations. In India, where there are some official records from which mortality totals have been reconstructed, cholera claimed an estimated fifteen million lives between 1817 and 1865; between then and 1947, it carried off, conservatively, another twenty-three million people. Cholera launched as a disease of globalization, and it subsequently became a disease of poverty and underdevelopment, intertwined with the patterns of global divergence during a decisive phase of transformation. It remains a devastating disease today, amid the ongoing seventh pandemic.[45]

Cholera was only the most dramatic example of a parasite that cunningly took advantage of the age of steamships and railroads. Yellow fever, influenza, and plague quite evidently belong on the list too. The vector-borne viral disease yellow fever had diffused from West Africa in the age of the slave trade. Although the tropics were the permanent homeland of yellow fever, summer shipping had long provided a means for the disease to make deadly seasonal forays farther north. The Atlantic coast of North America was struck repeatedly from the 1690s on. Steamships only extended its range. Outbreaks reached the Mediterranean and southern Europe sporadically in the early nineteenth century. Quarantine regulations were enforced to keep yellow fever off European shores. Aside from bubonic plague, the disease was the most important target of quarantine efforts until cholera took its place.[46]

For a time, from the 1820s to 1840s, it seemed that yellow fever had been corralled in its natural habitats. It was absent from Europe for a generation. But then, from the middle of the century, there was a "massive surge" of yellow fever. The long-feared potential of the disease to spread via steamship became a reality. The disease struck along the coasts of South America, Europe, and North America. In 1857, five thousand people died in an outbreak in Lisbon, and the disease appeared in French ports. In 1865 the disease arrived in Wales, where it docked along with a ship that had sailed from Cuba. The power of steamships to disperse the disease was evident inland as well. Yellow fever spread repeatedly up the Mississippi River. One of the worst outbreaks occurred in 1878, reaching Memphis, Tennessee, and killing at least twenty thousand people in total. It was against the backdrop of yellow fever's continued ravages that, in 1881, the Cuban physician Carlos Finlay presented his hypothesis that the disease was transmitted by mosquitos—a milestone on the path to systematic control of vector-borne disease.[47]

There are parallels in the history of influenza, except that unlike yellow fever, the flu is caused by a respiratory virus unbound by the limits of its insect vector. Its pandemic potential only continued to escalate into the twentieth century, such that the period from the late nineteenth century to present marks a distinct phase in the history of the infection. Influenza is a severe respiratory disease caused by several species of virus, the most important of which is *influenza A*. The virus has a segmented genome, made up of eight separate links of RNA. These segments can easily be reassorted—a kind of genetic mix and match—when different strains of the virus infect the same cell. The flu is a virus of birds but can also infect mammals, like humans and pigs. The planet's billions of wild waterfowl form a natural reservoir for *influenza A*. Human influenza is a kind of long-lasting crossover event, in which a parasite of avian origin circulates in populations of an abundant global primate.[48]

The early history of influenza is obscure, but from the sixteenth century, large-scale waves of acute respiratory disease are attested every twenty or thirty years. With a few exceptions, these historic waves of pandemic influenza appear to have been relatively mild. The spread of influenza had always been limited by the speed of transportation. In the pandemic of 1781–82, it was noted by one observer that the disease spread exactly as fast as a horse could travel. The impact of steamships and railroads was not immediate. There was a surprising lull in the history of influenza in the middle of the nineteenth century. But in 1889, the virus returned with a vengeance. The beginning of the pandemic was heralded in central Asia in spring 1889, and after a few quiet months it spread rapidly in the fall. As a historian of the outbreak has noted, "This explosive spread was doubtlessly made possible by the extensive railroad network that connected Lisbon and London to Vienna and Moscow. Indeed, for the first time in history, virtually all contemporary observers linked influenza diffusion to transportation networks." This outbreak was truly global and recurred in many places in three successive years. It was moderately severe, with case fatality rates around 0.1–0.2 percent. Known as the "Russian flu" at the time, the collective experience of a global mortality event in the age of telegraphs made "pandemic" a household word.[49]

Unfortunately, the pandemic of 1889–92 was a portent of worse to come. The pandemic of 1918–19 was the ultimate manifestation of a disease event in the age of steamships and railroads. It was in absolute terms one of the single most deadly events in global history, claiming the lives of maybe fifty million victims. (Proportionately, though, its impact on global mortality was far less than that of the Black Death or post-Columbian epidemics, because human numbers were so much greater by 1918.) It infected perhaps one in three persons alive, making it probably the single most coordinated rapid attack by a parasite in the history of the planet.[50]

The genetic material of the 1918–19 influenza virus has been recovered (from tissues preserved in formaldehyde, rather than archaeological material). The pandemic was caused by an H1N1 strain of avian origins. Why it was so pathogenic remains partly mysterious, but this strain seems to have activated secondary bacterial infection, leading to pneumonia in severe cases. The virus struck the young and healthy unusually hard. The exact geographic source of the great influenza remains equally obscure. In early fall 1918, it was suddenly "everywhere at once," suggesting that the virus had been disseminating for months before it became apparent that a mortality crisis was already in progress. The pandemic crested in the winter and then returned a year later. The global impact was staggering, but uneven. In the United States, there were 548,000 deaths, about 0.5 percent of the population. In India, the precise mortality is disputed, but the best estimate is around fourteen million deaths, about 5 percent of the total population.[51]

The lingering impact of the 1918–19 pandemic is as remarkable as its explosive beginnings. We are still living through it. The virus that swept the globe in 1918 became a "founder virus," and it has fittingly been called the "mother of all pandemics." Every subsequent epidemic of *influenza A*, including the seasonal influenza outbreaks, has been caused by a descendant of the virus that caused the 1918–19 pandemic. This crossover event from birds to humans was thus exceptionally successful. And the threat of future genetic reassortments that spin off novel influenza strains, replaying the events of 1918–19, remains one of the most dangerous lurking threats to human health.[52]

The only disease that rivaled cholera and influenza for explosiveness in this period was the bubonic plague. In the preantibiotic era, this bacterial infection made one last campaign to become a world-shaking disease. The Second Plague Pandemic that started with the Black Death in the fourteenth century had never really ended. Outbreaks of the disease petered out in western Europe, but plague epidemics in eastern Europe and the Ottoman Empire continued through the eighteenth century and even beyond. What is traditionally known as the Third Plague Pandemic overlaps the Second Pandemic, chronologically and spatially. And the genetic evidence has revealed an even closer association between the two historic pandemics. The strain of plague that caused the Third Plague Pandemic actually descends from a lineage that had arisen during the Black Death. The Third Plague Pandemic is, genetically, an extension of the late medieval outbreak.[53]

The beginning of the Third Plague Pandemic is dated by convention to 1894, when the outbreak reached Guangzhou (Canton) and British-controlled Hong Kong. This chronology obscures the Chinese backstory of the pandemic, however, which has been traced by the historian Carol Benedict. Plague epidemics had been simmering since the 1770s in the southwestern province of Yunnan. In the later eighteenth century, demographic and economic growth brought humans into greater contact with local rodent reservoirs of the plague throughout the western part of the province. Trading networks helped the plague to strike farther to the east, inching closer to the populous coastal regions. The plague became a major problem during the conflicts between the Han Chinese center and the Muslim periphery; for most of the period between 1856 and 1873, Yunnan was the scene of a bloody civil war. The demographic toll was heavy: the registered population dropped from 7.5 million to 3 million, with famine, violence, and plague combining to account for the heavy losses.[54]

The arrival of plague in Guangzhou and Hong Kong in 1894 was the end point of plague's overland expansion stretching back more than a century. It was also a fateful new beginning. Guangzhou, perched on the mouth of the Pearl River, was under Qing control and home to more than two million residents. In the course of the outbreak, as many as one hundred thousand residents of the city perished. Eighty miles away was the British-ruled island of Hong Kong, a "commercial colossus." Half of China's imports passed through the entrepôt. Its slums were deplorable, and its medical infrastructure meager. At least six thousand residents died in summer 1894 from the plague.[55]

The plague outbreak in Hong Kong set off alarms worldwide, and it was soon the occasion for a scientific milestone. As news of the epidemic spread, the Japanese government dispatched a team of researchers led by Kitasato Shibasaburō, a bacteriologist who had trained in Robert Koch's lab in Berlin (figure 11.4). Three days after the arrival of the Japanese team, Alexandre Yersin, an acolyte of Louis Pasteur serving in the French colonial health service in Saigon, also slipped into Hong Kong. The race to identify the microbial cause of the disease was fiercely competitive. Priority is still murky: Shibasaburō seems to have looked

FIGURE 11.4. Photograph of Kitasato Shibasaburō, who raced to discover the plague bacterium in Hong Kong. Wellcome Collection (CC BY 4.0).

at the bacterium first and beat Yersin to publication. But the French scientist was only days behind, and his descriptions are regarded as superior. Yersin also emphasized the importance of rats in the plague cycle. Fairly or not, he is immortalized in the nomenclature of the species, *Yersinia pestis*.[56]

Once the plague-infested rodents reached this hub of global commerce, the plague spread farther than ever before, riding in the hulls of giant steamships bound for every port in the world. The global effort to disrupt the spread of the plague was unprecedented in its scale and coordination. Quarantine and fumigation were at the heart of a massive scheme to prevent the plague from becoming a replay of the Black Death. The plague reached San Francisco and ultimately seeded rodent populations in the western United States (where it still lurks in prairie dog colonies), but only a few hundred Americans ultimately perished. Similarly, despite wild fears in Europe, the Third Plague Pandemic was demographically negligible there, claiming only seven thousand or so victims. The plague reached East Africa, where it is still enzootic in places like Madagascar. But its direst effects were felt in Asia. It killed millions in China. And the most affected region during the Third Plague Pandemic was India. Conservatively, plague claimed twelve million victims in India during the course of the pandemic.[57]

It is easy to think of epidemic diseases like cholera, yellow fever, influenza, and plague as relics of a premodern past. In reality, each of these diseases seized the opportunities presented by motorized transport to become thoroughly modern diseases. Only in those few societies that had undergone the early health transition, and learned to control the wild oscillations of epidemic disease early on, could the mortality crises of modernity seem like something from another epoch. Indeed, the success of containment efforts in protecting industrializing societies from the new threats of the period might be ranked among the more underappreciated accomplishments of the wonderful century. Unfortunately, the benefits were not universally shared.

Globalizing Plant Disease

In summer 1889, Paris played host to the Universal Exposition—the tenth such convention since the first world's fair in London in 1851. In conjunction with the exposition of 1889, France also hosted the first International Congress of Agriculture, which gathered 1,400 experts and officials from around the globe to discuss the state of the industry.

Like the exposition, the congress was a venue for the exchange of ideas and innovations, with a touch of nationalist showmanship. But the congress was tinged by urgent misgivings about globalization. The French minister presiding at the congress, a fervent protectionist, opened the proceedings by decrying market integration, which had been "disastrous for the old nations," whose tired soils struggled to compete with the virgin fields of America and Russia. To make matters worse, global integration had also brought pests, blights, and rots to the farms of the world.[58]

The homogenization of human disease pools has exact parallels in the diseases of plants and animals. This phenomenon merits a brief detour in a history of infectious disease. The topic has been relatively neglected; though some of its individual pieces have received attention, the bigger picture has hardly ever been sketched, despite its importance and the obvious parallels with human health. The history of plant disease also illustrates the role of science, ingenuity, and public action in countering the dangers posed by new diseases. Yet there is not even a word that describes a spatially widespread outbreak of plant disease, such as *pandemic* for humans and *panzootic* for animals. Nonetheless, rapid, widespread outbreaks of plant disease have been an important part of humanity's efforts to feed itself.[59]

Plant diseases have plagued farmers since the dawn of agriculture. Parasitism of plants is a pervasive part of nature. But from the moment humans started the bioengineering project of farming—selecting particular species, manipulating desired genetic traits, reducing natural diversity—we have incentivized parasites to adapt to our favored breeds. Humanity's scheme to harvest energy from a few preferred species allows plant pathogens to thrive for a simple reason: the "environmental and genetic uniformity of the agricultural ecosystem." Modernity has supercharged the kind of ecological transformation that is conducive to the evolution of plant pathogens. Previously intricate patchworks of interdependent species have been slashed and burned, replaced with dense, monotonous rows of human-preferred energy producers. Industrialization accelerated the process, as did global trade that allowed specialization and further manipulation of genetic lines.[60]

The U.S. delegate to the International Congress of Agriculture in 1889 was Charles V. Riley, who organized the American exhibition in Paris. Riley was a key figure at a key moment. A native Londoner who immigrated to Illinois, he established the applied study of plant pests in the United States. He rose to prominence as the head of the Grasshopper Commission, an entity that he convinced the congress to create in response to a plague of grasshoppers that threatened American farming in the 1870s. He was the perfect person to represent the Americans in Paris; indeed, if you like French wine, you should count Riley a hero. He played a leading role in recognizing that certain American vine stocks could resist the *Phylloxera* aphid, a tiny sap-sucking insect that had come to threaten European vineyards (see figure 11.5). The insect is native to North America, and the importation of American vines in the 1850s or early 1860s inadvertently carried the pest to Europe. "Once steamships began plying the trade routes, the bug could survive the trip, alight in Europe, and, soon enough, find a marvelously undefended environment."[61]

The Great French Wine Blight threatened to wipe out millennia of viticultural craft. The *Phylloxera* pest spread with terrifying speed, and it struck farmers as a kind of "tuberculosis for grapes," causing the plants to weaken, rot, and die. The cause was identified, and cures were desperately sought as the pest ravaged vineyards across France. A third of France's grapes were ruined, and fear of losing the entire industry gripped the nation before a suitable solution was found. Although there were some advocates for chemical treatment, Riley and others—called the "Americanists"—promoted the solution of grafting European *vinifera* onto resistant rootstocks imported from across the Atlantic. The latter solution prevailed and worked splendidly. Riley was awarded the Legion of Honor by the French government just a few years after the congress.[62]

The Great French Wine Blight is famous enough in viticultural lore, but its larger context is not. The reason the French were importing the American vines that brought the pest in the first place was, in fact, to counter another introduced pathogen: powdery mildew. And then the success of the American rootstocks in providing resistance to *Phylloxera*

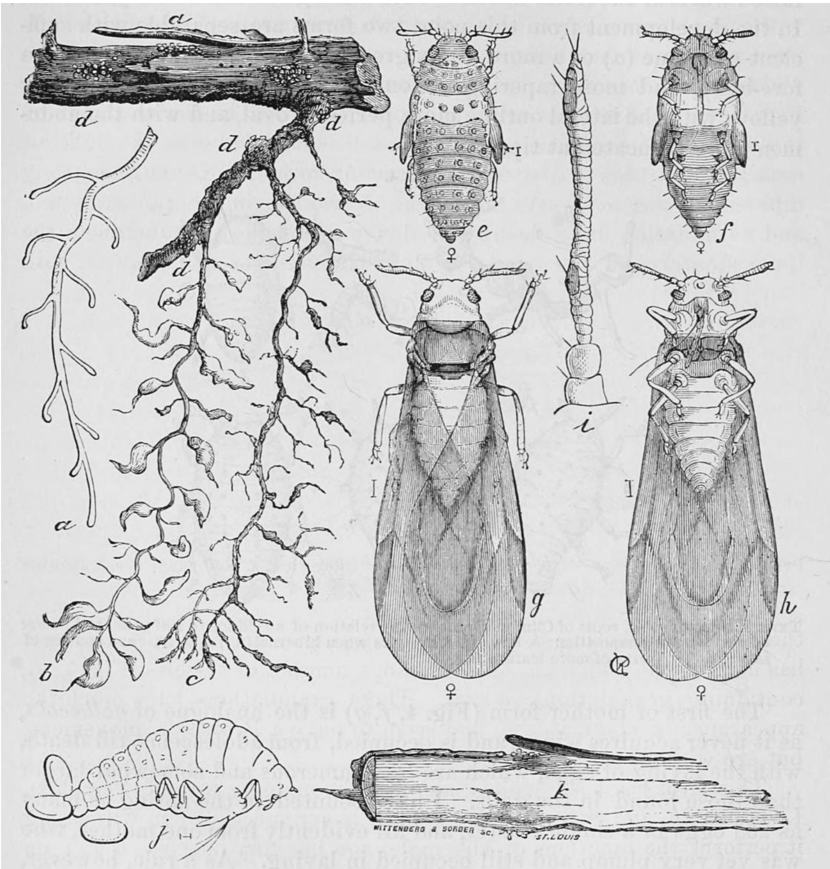

FIGURE 11.5. *Phylloxera*, cause of the Great French Wine Blight that threatened French vineyards. From *Popular Science*, 1874.

had an unwelcome sequel: it allowed downy mildew, yet another plant disease, to cross the Atlantic and establish in the vineyards of Europe. Every solution seemed to entail a new problem, and the succession of unintended biological consequences in the global wine industry is a parable for the endless evolutionary game between parasites and hosts, now fought out under human control.

The nineteenth century was the golden age for plant pests. The most spectacular and tragic example is the potato blight, also known as the late blight. Potatoes were an introduction from the New World, native to the Andes. Hardy, nutritious, and with a high yield per acre, potatoes became fundamental to Eurasian diets in the eighteenth century. Potatoes could be cultivated on marginal ground, in small plots, without animal traction, so they were a staple for the poor. In Ireland, almost a third of the arable acreage was given over to the potato—more than anywhere else in Europe. The daily consumption of potatoes per capita in Ireland amounted to two thousand calories. The ecological shock of the potato blight thus hit Ireland hardest. There had been omens in the decades leading into the crisis of the 1840s. Diseases had imperiled European potato harvests since the late eighteenth century. A viral disease known as potato curl, and a fungal infection known as dry rot, had struck in the 1830s. But these were nothing compared to the arrival of *Phytophthora infestans* in 1845.[63]

P. infestans is an oomycete, a fungus-like parasitic organism. *P. infestans* turns the outside of the tuber splotchy and turns the inside into a fetid mush. Some contemporaries called it the "potato cholera." It is native to South America, and by the early 1840s (possibly via Mexico) *P. infestans* had arrived on the eastern seaboard of the United States. It was first noticed around New York and Philadelphia and radiated outward over the next few years, reaching Canada and the Great Lakes. In 1845, it crossed the Atlantic, and in June of that year made its European debut in Belgium. Paleogenomic evidence has demonstrated that the American outbreak and the European outbreak were caused by the same lineage. The disease damaged the harvest in winter 1845 across swaths of western Europe. But in 1846, a full-on subsistence crisis unraveled when the potato harvest was almost completely lost. There was an 88 percent harvest reduction in Ireland, coincident with a terrible year for wheat, rye, and oats.[64]

The failed harvests were widespread across Europe, and the poor suffered in many regions, but only in Ireland did a famine follow. Ireland was not only uniquely dependent on the potato to feed its population but also uniquely reliant on a single varietal of potato, the lumper, that proved exceptionally susceptible to *P. infestans*. The Irish famine can be seen as a colonial crisis too, because an inept response from London, coinciding with a sharp turn toward free-market liberalism, failed to alleviate the hunger. Over a million people were sent to their graves in the shadow of the richest region on the planet. It was an ecological catastrophe produced by the conjunction of local agrarian circumstances and global disease networks—exacerbated by political failure.[65]

Like the potato blight of the 1840s, a number of plant diseases have threatened staple crops in modern times. As late as 1943, the Great Bengal Famine, caused by the fungal disease known as brown spot, led to widespread starvation and up to three million deaths. The westward expansion of the United States, as farms were cut into the Mississippi valley and Great Plains, created a new heartland for plant disease. Wild prairies, where new flowers bloomed by the week amid the tall native grass, were suddenly replaced with monotonous, rectilinear fields of grain. Rapid ecological homogenization, warm summers, and a high degree of market integration formed a deadly combination. Throughout the nineteenth century, American farmers faced dire outbreaks of cereal rusts and cereal smuts, fungal diseases that regularly damaged harvests. At times 20–30 percent of the harvest failed, and entire regions were temporarily forced to abandon wheat production rather than risk the ravages of rust. And where farming did prove resilient, it was due to savvy agricultural science that helped farmers stay a half step ahead of their microbial enemies. The federal government erected an infrastructure for agricultural (and veterinary) science early on, and precocious American agroscience is an underrated storyline in the global emergence of germ theory and the biochemical control of infectious disease.[66]

The nineteenth century also saw a great expansion of plantation agriculture. Plantation monoculture was imposed on once wondrously diverse tropical ecosystems. The swollen shoot and witches' broom of cocoa, the leaf blight of rubber, the mosaic disease of sugarcane, and a whole host of citrus fruit and banana diseases thwarted the hopes of capitalist enterprise. A paradigmatic example is the coffee leaf rust. The Industrial Revolution went hand in hand with an expansion of consumer demand for coffee, and suitable environments for growing the bean were sought worldwide by European capital interests. Wallace refers to this disease in his *Wonderful Century* as the quintessential example of how "the desire to get rich as quickly as possible has often defeated the planter's hopes."[67]

Bushes of the genus *Coffea* grow across equatorial Africa, but the species *Coffea arabica* produces especially rich and delicious beans. It was native to the highland forests of western Ethiopia but transplanted to Yemen long ago. As demand for coffee exploded, seeds from Yemen were used to establish coffee plantations throughout the tropics. The global coffee market was fed by production from South Asia and the East Indies, where small and medium farms lost ground to giant, monocultural plantations producing coffee with gangs of laborers. In Sri Lanka, "the virgin forests were entirely removed, producing unnatural conditions." The novelist Anthony Trollope commented on a visit that "the lovely sloping forests are going, and the very regular but ugly coffee plantations are taking their place."[68]

In 1869 a farmer on Sri Lanka noticed discoloration of his bushes. The British botanist stationed on the island was notified, and he in turn sent specimens to London. Coffee rust is caused by a fungus, *Hemileia vastatrix*. Like coffee, *H. vastatrix* is native to Ethiopia, but in a natural ecosystem its spread is constrained by climate controls. For centuries the Yemeni coffee industry had been spared because it is too hot and arid for the fungus. But the coffee plantations of South Asia were like an unguarded treasure left open to the parasite. Production of coffee plunged, and the remaining smallholders watched their already parlous condition ruined. The disease went global, and it remains a threat still. In the space of fifteen years in the late nineteenth century it reordered the global coffee economy. In the words of the historian Stuart McCook, who has written a close study of the episode, the coffee rust was "a product of conquest, of empire, of liberalism, of steamships, and of migrations."[69]

The plant diseases of the nineteenth century ruined small farmers and dashed the hopes of capitalists worldwide (see table 11.3). But they also inspired scientific research that would eventually deepen human control of planetary ecosystems. An array of regulatory measures, like quarantines and inspections, were mobilized, complemented by traditional biological approaches to disease control like selecting and breeding resistant

TABLE 11.3. Major Plant Diseases

Fungal	Viral	Insect	Other
Banana wilt	Barley yellow dwarf	Coffee bearer borer	Potato late blight
Brown spot of rice	Citrus tristeza	Cotton boll weevil	Root knot
Cereal rusts	Plum pox	Japanese beetle	Soybean cyst nematode
Cereal smuts	Potato curl or leafroll	Nutmeg canker beetle	Sugar beet cyst nematode
Chesnut blight	Sugar beet yellows		Wine blight (*Phylloxera*, aphid)
Coffee leaf rust	Sugarcane mosaic		
Downy mildew of grapes	Swollen shoot of cocoa		
Downy mildew of tobacco	Tobacco mosaic virus		
Dutch elm disease	Tomato spotted wilt virus		
Ergot of rye/wheat	Tomato yellow leaf curl		
Frosty pod rot of cacao			
Leaf blight of rubber			
Pine stem rusts			
Potato dry rot			
Powdery mildew of grapes			
Scab of wheat			
Sigatoka leaf spot of banana			
Southern corn leaf blight			
Witches' broom of cacao			

See also Agrios 2005.

strains. By the late nineteenth century, chemical interventions were increasingly used. Fungicides and insecticides were perfected and commercialized. It is telling that biological and chemical mechanisms of disease control were a dominant topic at the Paris Congress in 1889. As the economic historians Alan Olmstead and Paul Rhode have pointed out, agricultural progress in the nineteenth century was as dependent on biological science as mechanical innovation. Humanity's effort to feed itself requires the disinfection of the environment for our preferred species of plants. The same can be said of our favored animals.[70]

Global Animal Disease

In 1799, George Washington asked the U.S. consul in Tunis to acquire ten sheep from the Bey of Tunis. Washington was eager to promote the agricultural development of the young republic. "I know of no pursuit in which more real and important service can be rendered to any country, than by improving its agriculture, its breed of useful animals, and other branches of an husbandman's cares." English breeds of sheep struggled in America, so ten Tunisian sheep were shipped across the Atlantic. Only two—charmingly named Caramelli and Selina—survived the crossing. They were put in the care of a federal judge and friend of Washington, Richard Peters of Pennsylvania. He bred them prolifically, and Tunisian sheep became a sensational success and national favorite. John Adams loved them, and during the presidency of Thomas Jefferson they were known to graze on the White House lawn.[71]

Fifty years later, pigs started dying. From the 1850s, an infectious disease that contemporaries dubbed "hog cholera" became an explosive problem in America, and then globally. (There is also a bacterial disease known as fowl cholera, to go along with human, potato, and hog cholera, all of which are extremely unrelated.) Hog cholera is a highly lethal viral disease that causes fever, diarrhea, skin lesions, and a range of other symptoms in pigs. From 1856 to 1858, in the reconstruction of Alan Olmstead and Paul Rhode, "the disease swept across the Midwest and Northeast, often killing the entire population of infected herds." The disease was established across the continent, and then worldwide. Before it was brought under control, hog cholera was easily the most deadly disease of pigs in the world, and a constant threat to the pork industry.[72]

Hog cholera, properly known as classical swine fever, is one of the nineteenth century's many panzootics—emerging veterinary diseases that diffused swiftly and forcefully in the age of globalization. The genome of hog cholera has recently revealed its hidden evolutionary history. The family tree of classic swine fever virus shows that its closest known relative is, in fact, the Tunisian sheep virus. Classic swine fever virus evolved from Tunisian sheep virus following a host switch that happened in the late eighteenth century. Hog cholera was first described in the United States, and it seems likely that it was created by the great American experiment in adapting species from around the world to the agricultural possibilities of the continent. President Washington is, alas, indirectly to blame for this lamentable biological accident.[73]

The animal diseases of the nineteenth century mirror the dynamics of plant diseases. Natural ecosystems were replaced with landscapes of extreme genetic homogeneity. Domestic animal populations soared. Local farming gave way to agroindustry and long-distance shipping. Like plant disease outbreaks, the epizootics of the nineteenth century are illustrative of global patterns, and at times they sharply influenced the course of human history. But there is a crucial difference. With the rarest of exceptions, humans are not vulnerable to plant pathogens. By contrast, animal diseases are often dangerous to humans, and vice versa. Microbes that solve the riddles of the mammalian immune system pose a threat to cross the species barrier to us. Modernization, even though it has moved most of humanity out of the farmyard and into the city, has paradoxically drawn human and animal health closer together.

Livestock plagues are as old as recorded history. Even in classical antiquity, the integration of the steppe into the economic systems of Eurasia had already created a superhighway for animal germs across the giant continental landmass. At times, virulent animal plagues swept across herds on a massive scale. The rinderpest epizootic of the fourteenth century was a notorious catastrophe. Less is known about livestock disease outside of Europe in the earlier period, but rinderpest certainly was a problem from one end of Eurasia to another for centuries. In the calamitous seventeenth century, the disease wiped out entire herds in East Asia.[74]

A comprehensive history of animal disease in the modern world is yet to be written, and we can do no more than pull on a few threads. The modern era of animal disease launched in Europe in the eighteenth century, in the first phases of economic growth, preceding the transport innovations of steam and rail. Driven by urbanization and expanding markets, the agricultural sector saw continuous advances in specialization and growth in economies of scale. Nutritional habits also changed, as the members of the growing middle class incorporated meat into their regular diet. The interregional cattle trade grew rapidly, as western European wealth fueled specialized cattle rearing in eastern Europe. Hundreds of thousands of animals per year were moving from the Hungarian plain to the markets in the west. As the historian Karl Appuhn put it, "The eighteenth-century increase in the consumption of animal protein could not have happened without access to vast numbers of animals raised on central European grasslands."[75]

Market integration had ecological consequences, most notably transcontinental waves of rinderpest. Rinderpest is maybe the most destructive livestock disease in the annals of human farming; tellingly, it stands with smallpox as one of only two pathogens completely eradicated by human intervention. Rinderpest is caused by a virus whose closest known relative is the measles virus. This cattle disease has existed for thousands of years. For centuries, Europeans believed that it came from central Asia, and they were probably not wrong. Some breeds of steppe cattle are highly resistant to the disease, in contrast to the cattle of Europe, which are hopelessly susceptible to infection and suffer case fatality rates as high as 90 percent. As market integration drew western Europe into closer contact with the herds of the steppe, rinderpest inevitably followed.[76]

In 1709, a destructive panzootic diffused from east to west. Then, from 1745, the disease spread again over the entire continent, killing an estimated three million cattle. It ricocheted around the continent for the next few generations, and "Rinderpest was never absent from some part of Europe." Control measures like quarantine, inspection, and the culling of sick herds were refined. As with plant diseases, humanity's ecological dominance carried negative feedbacks for animal health, which in turn inspired scientific advance and governmental response. But the growth of commercial agriculture, and the transport revolution, outstripped the control measures, as the volume, velocity, and spatial reach of the cattle trade expanded in the nineteenth century. Again in the 1860s, western Europe found itself engulfed in a rinderpest panzootic.[77]

In England, this outbreak of cattle plague prompted Queen Victoria to authorize a prayer of confession and petition seeking divine intervention to stave off a disease reminiscent of an Old Testament scourge. The outbreak in England was traced back to cattle imported from Russia via the Baltic ports. From London the pestilence radiated outward across the farmyards of rural England. The government response was fragmented and disorganized. It took two years to bring the outbreak under control; by then three to four hundred thousand head of cattle—almost 10 percent of the national herd—had been lost. The destruction on the continent was equally vast. And yet, this outbreak was the beginning of the end . . . in Europe. Superior control measures, especially in Russia, brought rinderpest to heel in Europe in the last decades of the nineteenth century. The advent of refrigeration also reduced the need to import live cattle across national lines by making it possible to ship meat.[78]

Tragically, just as rinderpest was being brought under control in Europe, it was unloosed upon much of the Old World. The disease was already familiar in India, but modernization—principally in the form of market integration, population growth, and railways—opened a new chapter in the history of the disease from the 1860s. Huge epizootics struck the subcontinent. Although fatality rates may have been lower among Indian cattle more familiar with the virus, the disease undermined an already impoverished peasantry at a time of population increase, rapid transformation, famine, and human disease.[79]

Later in the century, rinderpest reached Africa. No animal plague was more consequential. Africa's massive herds of wild ungulates were also susceptible to the disease. The outbreak lasted from 1889 to 1898, overlapping the most intense phase of European imperialism. The virus was introduced via Ethiopia. The outbreak spread into the Sudan and south into the Great Lakes region. An Englishman in the employ of Cecil Rhodes, Alfred Sharpe, reported what he witnessed in 1892 in Zambia. "Here enormous quantities of game have died. . . . At the time of my passing up through these swamps the plague was at its height. Dead and dying beasts were all around. The first day I counted over forty dead pookoo within half a mile of my camp. Subsequently, on my return down the river, I saw scarcely any live game near the mouth, but the whole country was scattered with dead bodies." In 1896 the plague crossed the Zambezi River and entered South Africa, where it reached all the way to the cape before working its way north along the Atlantic coast.[80]

The African rinderpest panzootic was devastating, and the veterinary mortality coincided with the dislocations brought on by sudden colonization. Swaths of Africa lost up to 90 percent of their cattle. It ruined the subsistence base of herding groups like the Masai across the eastern part of the continent. In farming regions, animal traction was fundamental, and the loss was economically calamitous. Hides were a main source of clothing, dung was a main source of fuel and fertilizer, and ox-drawn carts were a major means of transportation across the east and south of the continent. Cattle were a form of money and a store of wealth, and they were integral to exchanges in the marriage market. A French missionary recorded a mournful dirge of those stricken:

> No more cattle, no more milk, what shall we eat?
> No more cattle, no more fuel, what shall we use for making fire?
> No more cattle, no more skin clothes, what shall we wear?
> No more cattle, no more marriages, how shall we marry?
> No more cattle, no more ploughing, what shall we eat and where shall we get money?[81]

The ecological shock reverberated for generations. The amazing long-range ecological dynamics of rinderpest in the Serengeti are the textbook model of pathogen-driven ecosystem control: the rise and fall of herbivores has affected predator populations, the advance and retreat of grasslands, and the frequency of fires—in short, the entire ecosystem. Food webs spanning from microbial parasite to apex predator have been linked in oscillatory dynamics, distantly perturbed by humanity's role in globalizing animal disease.[82]

Livestock diseases in the nineteenth century affected every species of farm animal. They moved breathtakingly fast and befuddled control efforts. The speed and spatial reach of these events is epitomized by the avian-equine influenza that struck Canada and the United States in 1872–73. In late September 1872, horses in Toronto started falling ill, showing respiratory symptoms. Toronto was quickly a "vast hospital for diseased horses." The equine influenza caused debilitating sickness, though fatality rates were low. By October 20, New York was struck, and two days later reports of horse disease are recorded in Massachusetts. The disease spread south to New Orleans, as well as west, reaching Wisconsin by early November and Missouri by December. In the eastern United States, the progression of the disease maps onto the railway network. The panzootic was manifestly transmitted from town to town by trains. However, as the scourge spread west, across the Great Plains and beyond, it is equally apparent that the flu spread on hoof. Following two major lines of westward expansion, one in the north and another in the south, it moved from horse to horse across the prairies and mountains until, the following spring, it reached the Pacific Coast.[83]

Before the triumph of the automobile, cities still depended utterly on horses, and urbanization had massively increased horse populations in the United States. The horse flu brought urban life to a sudden halt across the continent. From England, Charles Dickens wrote a detached summary of the outbreak. "The real inconveniences to the public, impediments to traffic, and interferences with business of all kinds, were not only annoying but productive of heavy pecuniary losses. The American cities have no underground railways, nor do they use the steam railways over ground, as we do, to relieve the street traffic, and connect suburban homes with city offices and workshops. Carts and drays for goods and merchandise, omnibuses and tram ways for passengers, are their sole means of conveyance, and, for these, horses are indispensable. At the height of the epidemic all the horses were practically useless, and business was at a standstill." America was horse country, halted in its tracks by this virus.[84]

As modern economic growth liberated ever greater numbers of humans from barebones subsistence, one of the first desires to be sated was the lust for meat. The creation of giant middle classes fueled the rise of the global beef industry, one of the most ecologically demanding systems of production on the planet. The increase in the number of beef cattle in the nineteenth century was astonishing. By 1900, there were four hundred million cows on planet Earth. As beef became synonymous with American prosperity, and as vast tracts of the interior were given over to cattle ranching, disease inevitably followed. The United States managed to keep rinderpest out, but other infections like bovine pleuropneumonia and foot-and-mouth disease posed serious threats to the industry. The most gruesome was a tick-borne disease known as Texas fever. The southern longhorn breeds were resistant to the infection, but they carried it north on cattle drives bound for railheads that

FIGURE 11.6. President Taft watches cattle dipping in 1909. To disrupt transmission of tick-borne Texas fever, Oklahomans required cattle arriving from Texas to be submerged in crude oil. Frederick S. Barde Collection, Oklahoma Historical Society.

would connect them to the stockyards and slaughterhouses of Chicago. The cows of the Midwest were susceptible to the disease, and regional politics became bitter (see figure 11.6).[85]

Industrial-scale agriculture creates evolutionary breeding grounds for pathogens. Where large mammals are crammed together by the thousands, pathogens can experiment and potentially cross to humans. Consider something as simple as the common cold, caused by an array of respiratory viruses including rhinoviruses, adenoviruses, and coronaviruses. Four (now five) of the coronaviruses are endemic to humans and virtually ubiquitous. You have almost certainly been infected with coronaviruses at some point in your life. They are relatively avirulent, and more of a nuisance than a threat, a virtual rite of passage for membership in human society. But their genomes unveil an otherwise invisible story about how humans came to have so many microbial enemies that infect our airways.[86]

Human coronavirus OC43 is one of these worldwide agents of the common cold. The closest relative of OC43 is the bovine coronavirus, a pathogen that causes relatively mild respiratory disease in cattle. In turn, these two coronaviruses share a common ancestor with another virus that causes disease in pigs. All three shared an ancestor around two hundred years ago, when the branch that includes human and bovine coronavirus split apart. The human coronavirus diverged from the ancestor it shared with the cattle virus sometime around 1890. The human disease caused by OC43 is not an ancient affliction; it joined the roster of human illnesses only in the midst of humanity's great reordering of planetary biota to slake our hunger for beef. The modern global meat industry gave us the common cold—or at least one of its most widespread agents.[87]

Disease, Power, and Globalization

Spring, 1885: As one international conference adjourned in Berlin, another convened in Rome. The Berlin Conference was the most decisive moment in the "scramble for Africa," the process by which the European powers partitioned a continent to delineate imperial territories. Meanwhile, in Rome, the sixth International Sanitary Conference met to discuss how the threat of contagious disease, above all cholera, could be safely met in an increasingly connected world. Although the Berlin Conference is remembered as an infamous moment in the history of colonialism while the Rome conference is celebrated as a precursor to modern global public health, the two meetings have more in common than it might first appear. Both conferences were European-dominated attempts to solve the problems presented by a new global order through negotiation among nation-states.

The two decades between the middle of the 1860s and 1880s were decisive in making this new order. Three interrelated processes coalesced with gathering speed in these pivotal years. The first was a turning of the tide in the control of infectious disease in industrializing societies. We will consider this momentous transition in the next chapter, but the permanent increase in life expectancy in places like western Europe dates to this moment. There is no single explanation for such a profound change, but at last sanitary reform, germ theory, and the hygiene revolution gave human societies control over infectious disease.

In tandem with these internal improvements and the confidence they engendered, two more international dynamics played out in these decades, symbolized by the conferences of 1885: the "globalization" of public health and the advent of high European imperialism. In describing the globalization of public health in the middle of the nineteenth century, we should neither diminish the precedents for international cooperation that had come before, nor overstate the aims of the scientists and diplomats who gathered with limited goals and scant formal power to achieve them. But both the cultural and institutional frameworks to envision global public health were irreversibly altered.

Italian city-states had entered cooperative agreements concerning plague and quarantine from at least the seventeenth century. In the eighteenth century, port cities from France and Italy to the Ottoman Empire collaborated on surveillance and control policies. These were limited efforts to coordinate and standardize quarantine policies. A major breakthrough came in the 1830s, when the pasha of Egypt, Muhammad Ali, asked the foreign consuls of Egypt to establish a consular commission of health to regularize quarantine in Egyptian ports and build a lazaretto (a detention station for those infected or suspected of infection), all in the name of containing cholera and plague. Tunisia followed suit. The ultimate purpose of these efforts was to ensure the unobstructed flow of trade through the Mediterranean. The consular commissions were the germ of new international cooperation on matters of health. They spurred visions of even broader collaboration. As early as the 1830s, the French were calling for an international conference to negotiate fair standards of quarantine in the Mediterranean. But inertia and diplomatic tensions stalled progress until the 1850s.[88]

The first International Sanitary Conference was at last held in Paris, in 1851. Ten conferences would follow over the course of the next fifty years. The immediate impetus was cholera; indeed, until the recrudescence of plague in the 1890s, cholera was the pressing concern behind the International Sanitary Conferences. In no small measure, international cooperation on matters of public health was propelled into a new age because of European dread of this fecal-oral pathogen.[89]

The larger context of the International Sanitary Conferences was both technological and cultural. New technologies of transportation and communication had brought the world into closer contact, with all the exhilaration and foreboding that such proximity entailed. One of the delegates at the first conference captured this sensibility: "Today, as steam power has made communication so swift, as thoughts, associated to electricity, travel the immensity of space in a moment, as, in a word, man attempts to nullify time and space," new approaches to the control of disease were urgently needed. The danger of distant disease in an interconnected world was palpable. He went on, "The Asiatic cholera, profiting, like man, from the modern discoveries, makes its incursions much easier than fifty years ago, and it spreads afar with all the rapidity of steamships and railways."[90]

The more subtle context for these International Sanitary Conferences was the growing spirit of internationalism itself. Fittingly, the very year that the first International Sanitary Conference took place in Paris, the Great Exhibition in London inaugurated the tradition of world's fairs (the 1900 Paris Exposition visited by Henry Adams was the thirteenth). Beyond these famous gatherings, the nineteenth century saw an "explosion" of international events of all types. In one comprehensive tally, there were 24 international meetings in the first half of the century and almost 1,400 in the second half. These congresses promoted cooperation on everything from agriculture to postal service, and led to the standardization of weights and measures (in 1875), time zones (1884), and the classification of disease (from 1893). The ordering of medical knowledge took on broader dimensions. Europeans had been interested in tropical disease since the beginning of colonization, but knowledge about global health was projected onto a global frame in the nineteenth century. The first global map of diseases was made in 1827. The field of "medical geography" sought to gather information systematically about the prevalence of disease in all parts of the world. Global health could now be envisioned in planetary perspective.[91]

The kind of internationalism embodied in the sanitary conferences, paradoxically, worked to strengthen the power of the nation-state. The greater volume and ease of movement across borders in the nineteenth century generated a sharper definition of those very borders. The aim of global sanitary cooperation was to create what has been called, in a brilliant metaphor, "semipermeable membranes." The world would be made safe for globalization because stronger nation-states could control what passed across borders, on what terms. There was expansion in the administrative technologies that grew out of quarantine: visas, bills of health, sanitary passports, and other forms of state control over citizens, merchants, pilgrims, migrants, and other travelers. The vision of globalization that resulted was not a borderless world inhabited by a common human race, but a world of nation-states and citizens where colonialism and commerce could proceed safely, which meant on Europe's terms.[92]

It is easy enough to insist on the limited aims and even more limited practical achievements of the sanitary conferences. Controlling the menace of "Oriental" diseases was hardly a humanitarian vision. The international conferences were patently Eurocentric, especially in the beginning. Few of the conventions were ratified until later in the century. The British were truculent, resistant to any infringement on their power at home or in the colonies. But from the beginning, the conception was novel. Countries sent both diplomats and medical scientists. By the 1880s representation had broadened, with delegations from the United States, South America, India, Japan, and eastern Europe joining the traditional western European and Turkish members. The conferences helped to foster international scientific networks, and they brought the British to the table. In sum, the International Sanitary Conferences, for all their limitations, form an important chapter in the emergence of global public health.

In these same decades, European geopolitical advantage became overwhelming. Combined with the expansion of global trade and fierce but sublimated interstate rivalry in Europe, the age of "high European imperialism" took shape. In 1800, Europeans already occupied or commanded 35 percent of the earth's land surface; on the eve of World War I, the figure had risen to 84 percent. A "first age of imperialism" from the

1760s saw the British establish control over much of India and the French establish an empire in North Africa. In addition to these overseas imperial ventures, contiguous land-based expansion by Russia and later the United States and Canada must also count as a form of imperial expansion. From the 1880s, an even more explosive phase of imperialism, the classic or high European imperialism, unfolded. The "scramble for Africa" saw a handful of European powers carve up the continent in the space of a decade. In parallel, the British also expanded their influence in Asia by occupying Burma, while the French seized Indochina to keep pace.[93]

The importance of disease in the dynamics of power was nothing new, but its role started to change. For two centuries after Columbus's Atlantic crossing, microbes had amplified European power over indigenous societies. The unification of the tropics created stark gradients of infectious disease in the New World that ultimately loosened the grip of European states over some of their possessions. In the long run, European settlement was most prolific in the healthier temperate climates. New regions like Australia, New Zealand, South Africa, and Argentina increasingly became home to self-reproducing settler societies.[94]

The heavy disease burden of the Old World tropics had made the equatorial zone into the proverbial "white man's grave." Diseases imposed almost unimaginably heavy costs on explorers, merchants, missionaries, and armies until the mid-nineteenth century. Around 1800, the death rates of European troops stationed in Africa were stunningly high. The historian Philip Curtin has carefully reconstructed the dangers faced by Europeans who ventured to equatorial regions. Annual mortality of 50 percent or more was not unusual. But gradually, military medicine became a major source of European power and weakened the invisible force field of infectious disease that had protected African and Asian societies against hostile takeover. The prospects of troops deployed in tropical climates improved. Military medicine, in general, was a field of steady advances between 1750 and 1850. The earliest gains were achieved by hygiene and clean water; then a sort of "magic bullet" was found in the form of quinine.[95]

Quinine is the active alkaloid compound of cinchona bark; in 1820, French chemists extracted it, allowing the drug to be manufactured in refined form. Quinine was immediately effective as a treatment for vivax malaria: if taken at the onset of symptoms, it aided in the patient's recovery. But it took time for the drug's potential against falciparum malaria to be recognized. Small dosages of quinine taken after an infection has started are insufficient. The idea of using high-dosage quinine as a prophylactic was not immediately obvious. It took good fortune and then careful experimentation before the medical virtues of prophylactic quinine were recognized and accepted. A highly publicized expedition up the Niger River in 1854 used prophylactic quinine to great success. Thereafter, death rates among Europeans in the tropics fell precipitously. The miraculous effect of quinine, however, can be overstated. Africa would not have been opened without advances in the use of *actual* bullets: the breech-loading rifle and the Maxim gun concentrated European power in these same years. In tandem, life-giving medicine and death-dealing machine guns opened the interior of Africa to European exploitation.[96]

The Berlin Conference defined the borders of European control in Africa. It drew geometric lines to create artificial territories where once patchworks of societies had lived in uneasy equilibrium with their dangerous disease environments. The rinderpest panzootic was only the most spectacular health catastrophe that followed European colonization. European takeover was motivated in part by commercial ambitions—a desire for minerals, rubber, palm oil, and other tropical crops. The extraction that followed—requiring roads and railways, urbanization and deforestation—disrupted what delicate balances did exist. The integration of the continent into global markets meant exposure to all the world's pathogens, with virtually no modern infrastructure to mitigate the risks, in addition to a worsening of tropical diseases. Predictably, the results were grim. To note just one example, the influenza of 1918–19 has been called "probably the greatest short-term demographic disaster in the history" of sub-Saharan Africa. In the earliest colonial documents, the mortality rates recorded are abysmal, reflecting a health situation created when the natural disease environment of Africa was suddenly and brutally incorporated into the global network of human diseases. In the words of the historian Emmanuel Akyeampong: "the divergence between knowledge and power was an important paradox of this period: Africans who had enough knowledge about their environment and knew how to manage it to keep endemic diseases at a low level were politically disempowered, and Europeans who now had political power lacked knowledge of the African environment."[97]

Global Divergence

"The world is quite vast," says one of the characters of Jules Verne's *Around the World in Eighty Days*, published in 1872. "It used to be," replies the protagonist, Phileas Fogg. Transportation technologies had made the world smaller, both for humans and for the microbes that exploit our success. Paradoxically, the ecological feedbacks of technological advance caused increases in life expectancy to stall in the mid-nineteenth century, even in western Europe. But as we will see in the next chapter, advances then resumed, and now moved faster than ever. Not only that, but they rippled outward; good health went global, as people all over the world exuberantly seized the opportunity to improve their lives. But the earlier onset of progress in western societies coincided with catastrophe in much of the world. In consequence, global divergences in health may have reached their maxima in the early twentieth century.

The lack of good data obscures the overall global trends, but we should not exclude the possibility that in large parts of the world, life expectancy stagnated or even declined in the "wonderful century." Certainly that seems to have been the pattern in India, where the British colonial administration started taking censuses in the 1870s and tracking vital rates. By the time estimates are possible, from the 1870s, life expectancy at birth was a dismal twenty-four to twenty-five years. Then it fell, reaching a nadir in the 1890s in the low twenties, which is about the lowest that life expectancy could have been for any sustained period of time in India's history. It languished there for another generation, and sustained improvements did not begin until the 1920s.[98]

The British believed that their administration conferred the blessings of civilization on their colonial subjects. On leaving office after eight years as governor-general of India in 1856, Lord Dalhousie claimed with pride that he had introduced "three great engines of social improvement" to India: the railway, the electric telegraph, and uniform postage. But it was precisely these technologies of integration and modernization that also exacerbated the disease burden. India was cholera's birthplace as well as the region most affected by it. The Third Plague Pandemic was a global event that hit India hardest. And the influenza of 1918–19 claimed more victims in India than anywhere else. Worse still, modernization made endemic diseases like tuberculosis, smallpox, and especially malaria a greater problem.[99]

The Indian intellectual and civil servant Romesh Dutt witnessed firsthand the paradoxes of development across India. He believed that colonization had led to simplification in the Indian economy, while British taxation contributed to food shortage. On top of that, the ecological transformation of the subcontinent was deadly. He was serving as a magistrate in West Bengal in 1890 when he saw how diseases like malaria had taken hold. The region of Burdwan once had a reputation for being "healthy and flourishing." "How changed the district is now, with its malaria fever! The fever has spread north and south, east and west, over both banks of the Hughli River, and over the whole of West Bengal. It is a national calamity which affects and enfeebles twenty millions of the people." In the name of progress, the course of the Ganges was altered and the small channels and watercourses that once flowed had turned into stagnant pools and rice fields. Mosquitos multiplied. "Villages all over the district were desolated." From the mid-nineteenth century, malaria killed around two million people per year in India. By one estimate, "malaria accounted for between a quarter and a third of all deaths in India during 1821–71." In the later period, between 1890 and 1920, malaria probably took twenty million lives in India, and debilitated many tens of millions more.[100]

The negative feedbacks of global modernization were severe. The wrenching passage to modernity has had lingering effects on patterns of development, its imprint far from vanished today. And this chapter between two periods of progress reminds us that the rapid successes soon to follow have been achieved by containing ecological pressures that continue to build in the era of human domination.

importance of these measures for the health of both themselves and their children, although some of the improvements resulted from cultural changes in architectural fashion and personal taste" (Razzell 2007, 121).

84. Dobson 1980, 1997.

85. See especially Riley 1986 on drainage and its intellectual context.

86. Heberden 1813.

87. Riley 1981. See the remarkable compilation of data in Haines and Shlomowitz 1998, which concludes (46) that there was a "percolation of experimental sanitary ideas and practices emerging from some institutions and naval ships in the last quarter of the eighteenth century and widely practised in later decades."

88. See Igler 2013 for the background of these voyages and, with Igler 2004, a guide to wider debates about contact, disease, and depopulation.

Chapter 11

1. A Feb. 20, 1801, letter from Adams to Jefferson is quoted in Oberg 2006, 23–24. On his experience with scarlet fever, see Adams 1918, chapter 1.

2. Wallace 1899, vii.

3. Wallace 1899, 340–41.

4. Headrick 1981; Watts 1997. One could also follow these themes through the rich literature on colonization and medicine (e.g., Arnold 1993; Harrison 1994).

5. These uniformities are a major theme of Bayly 2004, 1: "As world events became more interconnected and interdependent, so forms of human action adjusted to each other and came to resemble each other around the world." For the word *pandemic*, see below.

6. For quantification of imperial scales, see Etemad 2007. On the Great Divergence in living standards, see Bolt et al. 2018; Broadberry, Guan, and Li 2018; Broadberry et al. 2015; Maddison 2007b; Clark 2007; Broadberry and Gupta 2006; and Broadberry, Custodis, and Gupta 2015. On life expectancy, see below.

7. Close 1865, 17.

8. For population figures, I follow the synthesis presented in HYDE 3.1 (Klein Goldewijk et al. 2011). On the Great Escape, see Fogel 2004 and Deaton 2013. See the Maddison database (Bolt et al. 2018) for income figures.

9. Allen 2009.

10. See Gordon 2016 for an American-focused account. Easterlin 1996; Mokyr 1999; Smil 2005.

11. McNeill 2000; Smil 2017.

12. See Jonsson 2014 on cornucopianism. For the early modern exhaustion of resources, see Richards 2003 and Brooke and Otter 2016.

13. For this summary, and the data in table 1, see Osterhammel 2014, 121.

14. The "disaster of the century" quote comes from Osterhammel 2014, 124.

15. Rowe 2009. See Davis 2001 on the famines.

16. For the crises generally, see Rowe 2009, 165–74. For the demographic context, see Yi et al. 2016; Chen and Kung 2016; Baten et al. 2010; and Maddison 2007a. See Lee and Feng 2009 for an interpretation of Chinese demographic growth critical of Malthus.

17. On India and disease, see below. On the famines, see Roy 2000, 277–78, and Dyson 2018, 103–5, 134–40.

18. For Hawai'i, see especially Archer 2018. See more generally McArthur 1967; Cliff and Haggett 1985; Cliff, Haggett, and Smallman-Raynor 1993; Morens 1998; Igler 2004 and 2013; and La Croix 2019. On the journey of the king and queen, see Shulman, Shulman, and Sims 2009.

19. On Africa's demography in the big picture, see Iliffe 2017. For population figures and stasis, see Manning 2010, 266. On the epidemiological disaster, see Ransford 1983. See also Akyeampong 2006, 195–201.

20. Hohenberg and Lees 1985; Lenger 2012; Osterhammel 2014, 241–321.

21. Clark 2009. On Chicago, see Cronon 1991.

22. See Melosi 2008 for a perspective from America. See chapter 12.

23. "No other epoch . . ." is quoted from Osterhammel 2014, 154. McKeown 2004. On the settler revolution, see Belich 2009. On contract labor (focused on the United States), see Cohen 1995. For the background to the land runs, see Debo 1940.

24. Headrick 1981.

25. Bagwell 1988. The "railroad fever" quite comes from Headrick 1981, 181. The "one short interruption" quote comes from Osterhammel 2014, 717.

26. Findlay and O'Rourke 2007, 365–428. On trade and disease, see especially Harrison 2012.

27. See Morens, Folkers, and Fauci 2009 on the rise of the term in the late nineteenth century. Webster's 1828 dictionary defined pandemic as "incident to a whole people; epidemic; as a pandemic disease." See also Honigsbaum 2014; McMillen 2016.

28. The "swamped" quote comes from Green and Jones 2020, 35.

29. Hamlin 2009, 4. Historians of medicine and historians of society have found cholera a rich topic. From a vast literature, see Pollitzer 1954; McGrew 1960; Briggs 1961; Rosenberg 1962; McGrew 1965; Morris 1976; Durey 1979; Delaporte 1986; Bourdelais and Raulot 1987; Evans 1987 and 1988; Snowden 1995; MacPherson 1998; Echenberg 2011; and Harrison 2020.

30. Barua and Greenough 1992, 2–7; Hamlin 2009, 19–20. Classic overviews of cholera are found in Pollitzer 1954; Barua and Greenough 1992; and Wachsmuth, Blake, and Olsvik 1994.

31. *V. cholera* is an old and widespread environmental bacterium. Its natural home is the brackish water of tidal estuaries, where rivers meet the ocean. *V. cholera* is an exceptionally diverse species, with more than two hundred different types (or serogroups). Many of these are free-living aquatic bacteria, or they are adapted to live on the surface of marine creatures like copepods, tiny crustaceans that are ubiquitous in the ocean waters. Wherever you are on the planet, *V. cholerae* lurks in an estuary near you. A few of these strains of *V. cholerae* will cause sickness in humans if ingested, in essence a kind of food poisoning. But these are dead-end infections and not the cause of the historic cholera pandemics. Human cholera is the story of how one lineage of an omnipresent aquatic bacterium adapted to the strange environment of our gut. For the genetic evidence, see Devault et al. 2014; Boucher, Orata, and Alam 2015; Azarian et al. 2016; Boucher 2016; and Islam, Alam, and Boucher 2017. The convention of dividing the outbreaks of the nineteenth century into discrete "pandemics" has some grounding in reality but is based on limited perusal of the global evidence; the lack of total agreement on the dating of the pandemics reflects the ambiguity of the evidence, and, given that cholera could establish locally and persist, it is likely that some of the successive waves overlapped, so that the convention of discrete waves understates the complexity of the disease's history.

32. Boucher, Orata, and Alam 2015.

33. The "truly amazing" quote comes from Pollitzer 1954, 607. See Rabbani and Greenough 1992.

34. MacNamara 1876, 28–45; Pollitzer 1959; Barua 1992, 2–7.

35. Pollitzer 1954, 17–21.

36. On colonial Calcutta, see Bhattacharyya 2018. See Harrison 2015 on commerce and disease.

37. Pollitzer 1954, 21–31; Barua 1992, 8–12.

38. The cholera outbreak in Hamburg has been the object of a masterful study (Evans 1987).

39. On Zanzibar, see Gray 1962.

40. Christie 1876. See Echenberg 2011, 52–64, for an appreciative assessment of Christie and his work.

41. When cholera reached Zanzibar in December, it was not the first time the disease had struck the island, but memory of the earlier pandemics was already hazy. Christie could not find solid evidence that the first cholera pandemic, which started in 1817, had reached the island, but he believed that it likely had. Similarly, details of the second pandemic in the 1830s were "exceedingly scant." After two decades of reprieve, cholera returned in 1858. This, the third pandemic of cholera, was firmly attested in Zanzibar. Cholera arrived on the Somali coast with the first appearance of the *dhows*, the traditional sailing vessels of the Indian Ocean. Then it crept inexorably down the coast. The British adventurer Richard Burton was just south of Zanzibar when it arrived, and he recorded its destructiveness. Christie also had access to the papers of the British consul in Zanzibar at the time, who estimated seven to eight thousand deaths in the main city, and twenty thousand for the island as a whole. Christie suspected that these figures were, if anything, an underestimate.

42. The explorer David Livingstone claimed the island could be smelled from two miles away and proposed it be renamed Stinkibar. The Zanzibar city quotes are from Christie 1876, 271.

43. The "suddenly ill" quote is from Christie 1876, 367. "The skin . . ." is quoted from Christie 1876, 378–79. The "intellectual faculties" quote is from Christie 1876, 379.

44. Christie 1876, 385. "At last . . ." is quoted from Christie 1876, 387. For the death tolls, see Christie 1876, 419.

45. On these contrasts, see Arnold 1993 and Watts 1997. See also Harrison 2020 for thoughts on the mortality estimates in the early outbreaks. On the origins of the seventh pandemic, see Hu et al. 2016. *V. cholerae* still causes about three million infections and about one hundred thousand deaths per year (Ali et al. 2015).

46. On North America, see Patterson 1992. On Europe, see Harrison 2012.

47. The "massive surge" quote is from Harrison 2012, 107. On the 1878 outbreak, see Patterson 1992, 859.

48. Webster et al. 1992; Baigent and McCauley 2003; Nelson and Holmes 2007; Rambaut et al. 2008; Taylor 2014.

49. For an influenza wave in the fourteenth century, see Bauch 2020. Patterson 1986; Pyle 1986; Beveridge 1991; Potter 2001; Honigsbaum 2014; Saunders-Hastings and Krewski 2016; Hill, Tildesley, and House 2017; Alibrandi 2018. On spreading at the speed of a horse, see Pyle 1986, 28. "This explosive spread . . ." is quoted from Pyle 1986, 31. Valleron et al. 2010.

50. Crosby 2003; Barry 2004; Taubenberger and Morens 2018.

51. On the genetic material, see Taubenberger et al. 1997 and 2005 and Nelson and Worobey 2018. For the death tolls, see Patterson and Pyle 1991; Johnson and Mueller 2002; and Spreeuwenberg, Kroneman, and Paget 2018. The "everywhere at once" quote is from Taubenberger and Morens 2019, 4. In general, see Morens and Fauci 2007. On India, see Chandra, Kuljanin, and Wray 2012.

52. Morens and Taubenberger 2018.

53. On the continuity of the second pandemic, see Panzac 1985; Bell 2019, 53–57; Varlik 2020. On Russia, where terrible outbreaks struck in the eighteenth century, see Alexander 2003. On genomics, see Wagner et al. 2014 and Spyrou et al. 2016.

54. This paragraph draws from Benedict 1996, an important history of plague in nineteenth century China.

55. The "colossus" quote comes from Echenberg 2007, 15; see this source also on the third pandemic more generally.

56. For Yersin's work, see Echenberg 2007, 32–38, and Velmet 2020, 24–31.

57. Arnold 1993; Harrison 1994; Echenberg 2002; Bramanti et al. 2019; Velmet 2020. On the death figures, see Klein 1973, Arnold 1993, and Echenberg 2007, 5.

58. Nützenadel 2008.

59. Olmstead and Rhode 2008, which focuses on the economics of American agriculture in the nineteenth century, offers one of the richest overviews of the importance of the topic. McCook 2006 and 2019, focused on coffee leaf rust, cover all of the main issues. Agrios 2005 is a helpful overview of plant disease. Cook 1913 has much information about tropical plant diseases. See Beinart and Middleton 2004 for thoughts on historicizing plant transfers.

60. Stukenbrock and McDonald 2008.

61. On Riley, see Sorensen et al. 2008 and 2019. "Once steamships . . ." is quoted from Gale 2011, 4.

62. Gale 2011; Simpson 2011, 36–37.

63. See especially Ó Gráda, Vanhaute, and Paping 2007. See McNeill 2000 for the place of the potato in world history.

64. On genomics, see Yoshida et al. 2013, Martin et al. 2015, and Saville et al. 2016. Bourke 1964.

65. Bourke 1964; Vanhaute, Paping, and Ó Gráda 2006.

66. See Olmstead and Rhode 2008, especially 41: "Wheat farmers were cursed by the Red Queen's dictum: they had to run hard just to stay in one place."

67. Wallace 1899, 373.

68. The "virgin forests" quote comes from Wallace 1899, 373. On Trollope, see McCook 2019, 38.

69. McCook 2019, 8.

70. See Riley 1889 for the American exhibit. Harrison 2012, 232–46. On fungicides, see Morton and Staub 2008. Overall, see the essays in Brown and Gilfoyle 2010 and the two monographs of Olmstead and Rhode (2008 and 2015) for the scientific and policy responses that followed.

71. Brier 2013.

72. Agricultural Research Service 1962. See Olmstead and Rhode 2015, 138–55, on hog cholera.

73. On the genomics, see Rios et al. 2017.

74. Spinage 2003 is the most compendious treatment of cattle plague. See Newfield 2012, 2013, and 2015 for early medieval cattle plagues. See Newfield 2009, as well as Slavin 2012, for the fourteenth-century panzootic. See McVety 2018 for the twentieth-century history of cattle plague. See Scott 1990 for a medical perspective.

75. Appuhn 2010, 278.

76. On resistance, see Roeder, Mariner, and Kock 2013. On the divergence from the shared ancestor with measles virus, see Düx et al. 2020.

77. The "never absent" quote is from Spinage 2003, 103. Harrison 2012, 212–24. Van Roosbroeck and Sundberg 2017. On eighteenth-century responses, see La Berge 1992, 17.

78. On Queen Victoria, see Spinage 2003, 389–90, and Robinson 2009.

79. Spinage 2003, 447–71.

80. Mack 1970; Phoofolo 1993; Spinage 2003, 497–681.

81. Phoofolo 1993, 118.

82. Plowright 1982; Dobson 2009.

83. Kheraj 2018, for railway transmission in the east. See Andrews 2021 for its spread in the west (and also on the nature and effects of the outbreak more generally).

84. Dickens 1873, 105. Although it was less sensational at the time, a massive outbreak of disease among birds, including domesticated chickens as well as wild waterfowl, was coincident with the equine influenza. The interplay between avian reservoirs of influenza virus and industrial poultry farming has been, and remains, one of the gravest threats to human well-being. The possibility has been mooted that the horse flu of 1872–73 was related to highly pathogenic avian influenza, given the extraordinary overlap between the bird outbreak and the equine influenza (Morens and Taubenberger 2010a and b).

85. On Texas fever, see Olmstead and Rhode 2015, 94–114, and Specht 2019, 145–52 (which is a compelling treatment more generally of the interplay between the rise of global capitalism and the ecology of beef production, with insights into the ecology of disease). For cattle numbers, see HYDE 3.1 (Klein Goldewijk et al. 2011); Skaggs 1986; Rimas and Fraser 2008; and Specht 2019; including on the ecological transformations required by large-scale capitalist beef production.

86. Forni et al. 2017; Decaro et al. 2020.

87. On the bovine coronavirus, see Saif 2010. On OC43, see Vijgen et al. 2005 and 2006.

88. Harrison 2012, 50–78, is the best account of these early efforts at coordination. See Panzac 1985, 456–92, on the importance of Ottoman involvement and enlistment of European help from the 1830s.

89. Howard-Jones 1975 is the fullest treatment of the International Sanitary Conferences, focused on the scientific/medical aspects. Barkhuus 1943; Bynum 1993; Huber 2006.

90. Huber 2006, 455.

91. Huber 2006. On the map of global disease, see Brömer 2000. See Valenčius 2000 on the rise of medical geography. Tworek 2019, focused on the twentieth century, draws out the connections between communications and global health.

92. Bashford 2004. On semipermeable membranes, see Huber 2006. For the continuation of these themes seen through the lens of twentieth-century Israel, see Seidelman 2020.

93. For these figures, see Headrick 1981. See also Etemad 2007 for more detailed reconstructions. See Osterhammel 2014, 59–60, on the "first" age of European imperialism. See Porter 1994 for a survey of high imperialism.

94. For the large-scale dynamics of power and disease, see Headrick 1981 and Watts 1997. For settler colonialism, see Bayly 1989 and Belich 2009.

95. Curtin 1989, 1998; Etemad 2007, 11–24.

96. Headrick 1981, 58–79, is the classic account of quinine as a "tool of empire." Etemad 2007, 31–36, is a balanced update, concluding that "quinine was a decisive innovation for the Europeans of West Africa."

97. On the partition of Africa, see Wesseling 1996. Akyeampong 2006, 196. On influenza, see Patterson and Pyle 1983.

98. Davis 1951; Das Gupta 1971; Visaria and Visaria 1982; Bhat 1989.

99. On malaria, see Klein 1973. On smallpox, see Banthia and Dyson 1999.

100. On Dutt, see Gupta 1911, 88. Klein 1973; Dyson 2018, 108; Klein 2001.

Chapter 12

1. I have used Stanford Luce's 2005 translation (Verne 2005). As with several of Verne's novels, the original version of the story was by Paschal Grousset, who sold a draft to the editor Pierre-Jules Hetzel, who then commissioned Verne to rewrite it.

2. Richardson 1876. On Richardson, see Otter 2008, 62–63, and Crook 2016, 1–4.

3. The "generation ago" quote comes from Kelley 1915. On the dominance of infectious disease as cause of death, even in some of the world's healthiest places like New England, see Noymer and Jarosz 2008. Mooney 2007 has noninfectious causes of death in a slight majority by the mid-nineteenth century, but uses restrictive definitions of infectious disease. On the mortality decline, see Preston 1976; Bengtsson, Fridlizius, and Ohlsson 1984; Mercer 1990; Schofield, Reher, and Bideau 1991; Chesnais 1992; Riley 2001; Fogel 2004; Bengtsson et al. 2004; Bourdelais 2006; Dyson 2010; Deaton 2013; and Mercer 2014.

4. I found the "suddenly started breeding" reference in Russell 2001, 7, ultimately from Lean, Hinrichsen, and Markham 1990.

5. On the Anthropocene concept, see below. For the microbiology of the Anthropocene, see Gillings and Paulsen 2014 and Hirschfeld 2020.

6. Mitchell 1998a; B. Mitchell 2011.

7. See B. Mitchell 2011 for the raw data for England/Wales; see Carter 2006, volume 1, for the United States. Mercer 1990; Hardy 1993a; Woods and Shelton 1997; Mercer 2014.

8. Although there are not good global cause-of-death data before the late twentieth century, James Riley has meticulously gathered different national data sets. Riley 2005a offers a wealth of information, and B. Mitchell 1998a and b, 2007, and 2011 collate data helpfully.

9. See Chadwick 1965 (originally published in 1842), 210. Hamlin 1998 persuasively argues that Chadwick's narrow focus on filth actually served to limit the attention on poverty as a cause of disease. Pickstone 1992.

10. Chadwick 1965, 422. Coleman 1982; Duffy 1990; La Berge 1992; Rosen 1993; Porter 1999; Barnes 2006; M. Brown 2008. See Latour 1993 for a classic account of transition from miasma to germ theory in France.

11. See Susser and Stein 2009, 73–97, on mid-nineteenth-century epidemiology. Steere-Williams 2020. In Britain, at least, miasmatist theory proved harmonious with laissez faire ideology. Free trade, social reform, and public health went hand in hand. By contrast, contagionism