

Twenty-First Century Plague

THE STORY OF SARS

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— Britta Erickson, *The Art of Xu Bing*



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1

INTRODUCTION

THE Sunway Lagoon Resort Hotel, half an hour's drive from Kuala Lumpur's international airport, is a large rose stone and glass complex decorated with arches and pillars and surmounted by a minaret-topped dome. The hotel's promotional literature describes it as Malaysia's most versatile convention and exhibition venue, the place to make the ultimate corporate statement. As an added enticement for the jaded convention goer, it also claims the world's largest surf wave pool, a theme park and a huge shopping complex. Despite these multiple attractions, business had been slow in the first half of 2003. The war in Iraq and then the ravages of a new disease, SARS, had kept both the tourists and the convention crowd away. Clearly, no one felt this was quite the right time to make the ultimate corporate statement.

But on June 17 the hotel was buzzing. The carpeted hallways and cavernous conference chambers were crowded with war veterans. They were veterans of wars that few people have heard of. Their battlefields were in places that never made the newspaper headlines: obscure villages and towns with names like Yambuku, Kikwit, Rustaq and Kohlu. And the enemies they fought were too small to see with the naked eye: micro-organisms like the Ebola or the influenza virus. Today though, they were meeting under the full glare of the world's media at a conference organized by the World Health Organization (WHO). A hundred days earlier SARS had swept across the world and suddenly the battles these veterans had fought against microbial disease had become of overwhelming importance to the world, upstaging the more conventional war in Iraq.

The war in Iraq and the invasion of human society by the SARS virus happened at around the same time. The disease first emerged in small outbreaks in southern China in the last few months of 2002, as US and British forces were being deployed in the Persian Gulf in preparation for an invasion. In the second week of March 2003, shortly

before the invasion of Iraq on March 20, the SARS virus erupted out of China into the wider world. And as US and British forces ploughed into Iraq, the SARS virus leaped across continents, setting off trails of infection in some of the busiest and most dynamic cities in the world. By some measures, the effects of this new disease were as devastating as a conventional war. By June 2003, over 8000 people had been infected in 32 countries all over the world, and over 900 had died, many of them young and healthy individuals who would normally have expected to live a full life.

The juxtaposition of these two forms of warfare awakened governments to the fact that microbial disease is as great a threat to national security as an invasion by a foreign army. In the US, the anthrax attacks in late 2001 had focused public attention on the way in which disease-causing pathogens could be used as terrorist weapons. But SARS hammered home the message that an infectious disease, even if not intentionally used as a weapon, could be as disruptive and costly as a conventional war. And unlike a conventional war, there was no prior warning of a microbial war: it erupted without notice, and swept through societies that were unprepared to fight it. The head of Hong Kong's public hospital network, Dr William Ho, described SARS as "the Pearl Harbour attack magnified many fold and in a rapidly escalating pattern. We hardly knew anything about the enemy in the beginning."¹

The analogy of war echoed throughout the SARS crisis. This was an attack by an unseen invader to which nations had to respond as they would to any other attack — by mobilizing the resources to repel the invader. For many countries it became clear that the real threat to security would come not from invading armies, but from unknown microbes. "We must remember that in this region, we are more likely to be invaded by microbes than by a foreign army," Malaysia's Health Minister Chua Jui Meng pointed out.²

This war by microbes targeted the vital infrastructure of society; in this case, the public health system. The virus first hit doctors, nurses and health care workers, mowing them down like soldiers on a battlefield. But unlike soldiers who are trained to face death, medical workers are trained to save lives. Without warning they found themselves thrown onto the front lines of a battle in which they were the cannon fodder. And like a guerrilla fighter, the SARS virus managed to turn public health systems to its own advantage: spreading in hospitals and finding new victims who would in turn take the disease out into the wider community. Not only was this a disease for which modern medicine had no cure, it was a disease that used the institutions of modern medicine to spread.

In the areas hit hardest by SARS, people experienced a fear their forefathers had lived with constantly: the dread of death from disease. The ghosts of an era when death from epidemics of plague, pneumonia and influenza was as routine as the changing of the seasons had returned to haunt a generation that had grown to believe that modern medicine had vanquished infectious diseases.

The economic cost of the disease was also devastating. In a little over three months, SARS touched every continent, and paralyzed some of the world's most dynamic cities and regions. The global economy lost about US\$30 billion in production, most of it in Asia. Governments clamped quarantines and other restrictions on travellers, reversing a decades-long global trend of loosening travel restrictions. Airports emptied, airlines cancelled flights and it appeared as if the virus had blocked the arteries of a networked, interconnected, globalized twenty-first century world.

Gro Harlem Brundtland, the then Director-General of the WHO, summed up the impact that a minute virus could have on the world:

We are dealing with a new disease striking a globalized society. We have seen its rapid international spread. We have seen stock markets move up or down according to the latest success or setback in the SARS situation. We have seen bustling transportation hubs go silent. We have seen SARS on the front pages and on our TV screens. We have seen the closure of hospitals, schools and borders. We have seen economic impact, population movements from affected cities and unwarranted discrimination.³

By June, when health experts from all over the world met in Malaysia, the worst of the epidemic was over. In three of the initial outbreak centres, Hong Kong, Vietnam and Singapore, there had been no recent cases of the disease. In Toronto, another of the cities to be hit hard by SARS, the outbreak was coming under control. It was only in mainland China and Taiwan that new cases were still being reported. But here too, the number of new cases was falling, and it was apparent that the epidemic was dying out. There was an understandable air of self-congratulation and mutual back-patting among the scientists and public health officials. Clearly, much had been achieved in 100 days. The epidemic had slowed, the virus causing the disease had been identified, a great deal had been learned about its method of transmission and significant clinical knowledge had been gathered on how best to treat the disease.

But there were also many disturbing, unanswered questions. How

was it possible that at the beginning of the twenty-first century, with the armamentarium of modern medicine at its disposal, humankind was still so vulnerable to disease-causing microbes? If this disease had erupted without warning and ambushed the world with such devastating effects, were there other new diseases waiting to attack in a similar way? Were we facing a century of new diseases?

Joshua Lederberg is a towering figure in the world of contemporary microbiology. He won the Nobel Prize in 1958 at the age of 33 for his work on genetic recombination in bacteria. For several decades, he has been a leading, and often lonely, voice warning of the threat to human society posed by viruses. "The threat of a major virus epidemic — a global pandemic, hangs over the head of the species at any time," he wrote in 1968.⁴ This was after a previously unknown virus infected 37 people in Marburg and Frankfurt in Germany, and in Belgrade, Yugoslavia, killing five of them. The virus had been transmitted to humans by African green monkeys being transported from Uganda to laboratories in Germany. The symptoms of the disease were horrifying. Patients' skin, hair and nails peeled off, blood erupted from every orifice and within two weeks the constant internal and external bleeding led to multiple organ failure.⁵

Because the disease broke out in a laboratory environment, it was contained before it had a chance to spread to the larger community. But for Lederberg, this was a classic example of the danger that the viral world posed to human society. A pandemic caused by exotic lethal viruses from the animal kingdom was an event for which the world needed to be prepared. And if the virus was virulent and readily transmissible, a worst-case scenario would be the decimation of the human race. "The survival of the human population is not a preordained evolutionary programme," he warned. The human presence on earth was challenged only by microbes, "the predator for which we remain the prey."⁶

In the case of the Marburg virus, Lederberg felt the world had a near miss. Rather than infecting human beings in a laboratory in Germany, the virus could "easily have established a large focus of infection in countries like India or China or South Vietnam, and in our present knowledge of virology, we would have been ill equipped to stop it from dominating the earth, with a half a billion casualties."⁷

In the late 1960s, Lederberg's apocalyptic warnings went against the contemporary belief that infectious diseases no longer posed a threat

to humankind. The discovery of penicillin by Alexander Fleming in 1928 and its mass production in the post-war years seemed to mark a decisive turning point in the human battle against infectious diseases. Penicillin and other antibiotics proved to be miraculously effective against an array of previously lethal bacterial diseases, including the plague, tuberculosis and pneumonia. Mortality rates from infectious diseases fell rapidly in the developed world and life expectancies rose. While viral diseases were resistant to antibiotics, antiviral drugs that targeted essential proteins required by viruses to cause infection soon arrived on the market. While the antivirals were not always effective, it only seemed a matter of time before science would make it possible to treat viral diseases with drugs in the way that bacterial diseases were treated.

Using these new drugs as well as vaccination, plans were laid in the 1950s and 60s to eradicate malaria, polio, tuberculosis and smallpox globally. The WHO declared that these diseases, which had afflicted humans from the earliest times, would soon be eradicated. Infectious diseases appeared to be a thing of the past, and the US Surgeon General reflected the spirit of the age when he declared in 1969 that "we can now close the book on infectious disease."⁸

The decades that followed proved him to be spectacularly wrong. As the twentieth century came to a close, it became apparent that with the exception of smallpox, which had been eliminated through a global vaccination campaign, all of the diseases targeted for eradication 40 years earlier were still flourishing. Tuberculosis remained one of the three largest causes of infectious disease deaths in the world, killing an estimated 1.6 million people a year. Roughly 2 billion people, or nearly a third of the world's population, were thought to be carrying the tuberculosis bacillus, though the majority would not develop the disease. Malaria was also resurgent, particularly in Africa.⁹

It was not merely that efforts to eradicate these diseases had failed. The organisms that caused these diseases had returned in new, drug-resistant forms. Penicillin, the first of the post-war wonder drugs, was also the first to become ineffective in the face of new generations of penicillin-resistant bacteria. Then other antibiotics began to fail as well. Soon experts began to predict the imminent arrival of a post-antibiotic age, when all the common antibiotics would cease to be effective.¹⁰

Besides the return of old diseases in new, drug-resistant forms, the last few decades of the twentieth century also saw the emergence of a host of new viral diseases, of which HIV/AIDS is the best-known. In the 20 years since the disease was identified, it has spread across the globe and become the largest public health threat now facing the world.

By 2003, there were an estimated 40 million people worldwide infected with the HIV virus, which was continuing to spread at a devastating rate. The WHO estimated that 14 000 people a day were contracting AIDS. But HIV/AIDS is only one of nearly 20 new diseases that have emerged since the 1970s. Of these, Ebola is the most lethal, with a fatality rate of over 80 percent. Others, like Nipah, Hendra and Hantavirus pulmonary syndrome, produce lower mortality rates, but like Ebola, have no cure. Lederberg's warnings about the threat posed by new viral diseases suddenly appeared remarkably prescient. During the 1980s and 90s, the study of emerging infectious diseases became the focus of urgent attention in the US, leading to a series of scientific reports warning of the threat posed by new microbes, and suggesting appropriate protective measures.¹¹

Lederberg and other scientists saw viruses as being uniquely dangerous for a number of reasons. First, unlike bacteria, against which newer generations of antibiotics could be developed, the very nature of a virus makes it far more difficult to develop effective antiviral drugs. Viral evolutionary patterns also result in the faster generation of mutant varieties than is the case with bacteria, making viruses a rapidly shifting target for both the human immune system and the manufacturers of vaccines and antiviral drugs.

Viruses evoke the same kinds of emotions in us as the great white shark or the giant carnivores from the age of the dinosaurs: a mixture of awe and terror at a form of life that is so basic, yet so perfectly suited to its ultimate purpose of preying on other forms of life. Unlike bacteria, which are large enough to possess all the biological mechanisms needed for independent life, viruses are the ultimate parasites. They are little more than minute ribbons of DNA or RNA wrapped in a protein casing. Viruses have no metabolism and they lack the ability to reproduce independently. As the microbiologist Dorothy Crawford put it, "viruses represent life stripped to the bare essentials."¹²

A virus comes to life only after it enters a living cell, whether a plant cell, an animal cell or even a bacteria. Once the virus penetrates the host cell, it engineers a molecular coup d'etat, and takes over the cell's machinery, which it then uses to reproduce itself. In the process, the host cell is severely weakened and eventually dies. The virus however, has achieved its purpose by using the cell to create thousands of copies of itself. It is the fundamental incompatibility of the aim of the virus, which is to find a host and take over its cells to manufacture new viruses, and the aim of the host, which is to preserve its own life, that makes the relationship between host and virus a battle, manifested as disease.

But the interaction between host and virus does not always lead to disease. Long-term adversaries often come to an agreement to live and let live, and this is what tends to happen over the long-run between a virus and its host. Most living creatures carry viral parasites with which they have lived and evolved over the centuries to reach a state of accommodation. The virus lives and reproduces within its natural host without causing the host any apparent harm. Most evolutionary biologists believe that this kind of symbiotic relationship is the equilibrium towards which virus and host evolve. It is not in the virus' interest to weaken the host so much that it dies prematurely: this forces the virus to find a constant supply of new hosts, and if that is not possible, the virus itself will die out. As Lederberg observed, "the host rapidly destroyed is a pyrrhic victory for the parasite."¹³ A better relationship is one in which the virus can reproduce over a long period of time within a healthy host.

The process of accommodation between virus and host can take centuries of co-evolution. Severe viral diseases tend to occur when viruses meet new hosts for the first time. Virus and host are unfamiliar with each other, and the reaction is strong. The host usually has no immunity to the new virus, often leading to fatal disease. All of the new viral diseases that have cropped up over the last few decades have been zoonotic, meaning they are caused when viruses that normally live in animal hosts jump to human hosts, causing severe infection.

The reasons for the increase in these kinds of encounters during the past 30 years lie in the disturbances to previously untouched ecosystems caused by human activity.¹⁴ Building roads and clearing virgin forests, for example, brings humans in contact with new viral species living in animals and insects. If a virus can jump from its host species to a human host, the result will be a viral infection. As we multiply and expand across the planet, occupying new areas of the earth's surface, the chances of encountering new infectious agents continues to increase. And we have been multiplying and expanding at a staggering rate, particularly over the last 100 years. In 1900, the earth's human population stood at around 1.6 billion. By 2000, there were over 6.3 billion people. By 2050, the earth will have to support an estimated 9 billion people.

These exploding numbers have led humans to enter ecosystems they have never entered before: jungles and forests have been cleared, swamps drained, roads constructed and towns and cities built in environments where animals, plants and microbes had lived stable, settled existences isolated from human advances for thousands of years. In the same way

that a wasps' nest is disturbed by a carelessly poked stick, human intrusion disturbs a variety of delicately balanced ecological relationships. And just as a swarm of angry wasps will attack an intruder, viruses, bacteria, parasites and insects respond to human intrusion by attempting to jump from their natural host to man. More often than not, they do not succeed. But when they do, the result can be a new infectious disease.

It usually takes more than a virus jumping from an animal to a human host to create an epidemic. The virus must be able to move easily between humans, and not merely occasionally from animals to humans. Fortunately, most of the new disease-causing viruses that have emerged in recent decades have been animal viruses that have not quite perfected their strategy for hopping from human to human. So while they may cause fearsome disease among those they infect, the disease rarely spreads far. The exceptions have been AIDS and SARS, both diseases caused by a virus with the ability to transmit easily between humans.

But even more than the nature of the virus, it is our own cultural and social practices — the way we live, the food we eat, our relationship with the environment — that create the conditions for a new disease-causing virus to gain a foothold and spread in the human population.

Consider the case of HIV/AIDS, which erupted almost simultaneously in the US and Africa in the early 1980s, and then raged across the world, mowing down young, healthy men and women to become the world's leading cause of death from infectious disease. The origins of HIV/AIDS are still shrouded in controversy, but the general consensus is that the HIV virus first passed to humans from monkeys in the rainforests of Central Africa.¹⁵

The HIV virus is related to a group of viruses known as the simian immunodeficiency viruses (SIV), which are found among a variety of monkeys and chimpanzees in the equatorial forests of Africa. The closest relative to HIV1, which causes the most virulent form of AIDS in humans, is a SIV virus that has been found in a few chimpanzees in Gabon and Zaire in the same area where the first human HIV cases were recorded.

Researchers who have tried to reconstruct the evolution of the virus have suggested that HIV could have first appeared in humans as early as the 1930s, when it was passed from captured chimpanzees to hunters through bites and cuts. Following these initial encounters, the virus continued to evolve over the decades, adapting to the human body, becoming more adept at transmitting between humans. At the same

time, contact between hunters and chimpanzees increased as roads built by logging companies opened up the rainforest and the demand for "bush meat" increased in the towns and cities of West and Central Africa.

The virus probably caused isolated epidemics among humans in small, rural African communities. But it had already begun to travel. In 1976, a Norwegian sailor who had travelled to West Africa died of a mysterious disease. His wife, who contracted the same disease, died as well. Years later, after AIDS had been identified as a new disease, their tissue samples were tested and found to be HIV-positive. Going further back in time, blood samples from a 48-year-old sailor who had died in New York in 1959 showed signs of HIV infection, as did samples from a 15-year-old boy who had died in St Louis, Missouri, in 1968. These isolated cases of the disease never exploded into an epidemic. It required major shifts in human behaviour to create the conditions for the virus to transmit between humans at a rate high enough to cause an epidemic.

The HIV virus is transmitted through bodily fluids, primarily blood and semen. In the US, the 1970s saw a fundamental shift in social mores that would provide the virus with an environment in which it could explode into an epidemic. This was a period when sexual behaviour in general was liberated from earlier constraints. And no one embraced this liberation more than the male homosexual community, which came out en masse in a series of gay pride marches and celebrated its new-found sexual confidence in an orgy of activity in bathhouses and clubs in New York and San Francisco, the two capitals of the gay liberation movement.

Anonymous sex with multiple partners as often as possible became a fundamental element of gay liberation. This provided an ideal environment for sexually transmitted diseases in general, and the HIV virus in particular, to transmit rapidly from human to human.

A second critical factor in the HIV/AIDS epidemic was the sharp explosion in the number of heroin users and the sharing of unsterilized needles, creating another environment in which a virus transmitted through blood could multiply rapidly. Overlap between the drug using and the male homosexual community allowed the virus to multiply in both groups.

A third source of new hosts for the virus was blood banks, which purchased blood from professional donors who were more often than not down and out drug addicts who needed money for their next fix. Until the late 1980s, when screening and treatment of blood and plasma supplies became routine, the virus was passed on from infected donors to blood recipients. These three elements: sexual liberation, increased

drug use and sharing of needles and blood donations provided the social and cultural backdrop for the AIDS epidemic in the US.

In Africa, the conditions that gave rise to the epidemic were different. Here, it was the armed conflicts, wars and economic upheavals of post-colonial Africa that created the social conditions for the virus to spread. During the 1970s and 80s, the Great Lakes region of Central Africa, which includes Zaire, Uganda, Tanzania, Rwanda and Burundi, was one of the most unstable areas in the world. The movement of soldiers, particularly between Tanzania and Uganda, and the disruption of traditional economies that sent men to search for work in urban centres, and women into prostitution in towns along major road and river routes, encouraged promiscuity and created the conditions for a virus that had previously affected only isolated communities to spread across Sub-Saharan Africa.

Besides transmitting sexually, the virus also spread in Africa due to poorly equipped hospitals and the repeated re-use of needles in much the same way that it had spread as a result of the sharing of needles among drug addicts in the West. Throughout history, social disruptions and economic distress have provided fertile soil for diseases to flourish. The spread of AIDS in Africa is only the latest example of this phenomenon.

The origins and epidemiology of HIV/AIDS are particularly complex and politically sensitive. In the case of other emerging diseases, the link between human intervention in natural ecosystems and the emergence of disease is more straightforward, as the story of the Nipah virus illustrates.¹⁶ In 1997, giant forest fires broke out in Kalimantan and Borneo in Indonesia, blanketing the region in acrid clouds of smoke. Large-scale burning of the forests to clear land for plantations and agriculture had sparked the fires, which spread rapidly due to unusually dry conditions caused by the El Nino effect. By the time the fires had burned out, 9.7 million hectares of forest land had been charred and 75 million people had been affected in some way or another.

But the fires were to have long-term consequences as well. In the autumn of 1998, a mysterious illness broke out in the Malaysian state of Perak. The early symptoms, high fever and muscle pains, were similar to flu. As the disease progressed however, the brain tissues of patients became inflamed, leading to convulsions and eventually coma. Doctors first thought the disease was Japanese encephalitis. But vaccination against encephalitis did little to stop its spread. No drugs seemed to work, and almost half of those who developed symptoms died.

One interesting feature of the outbreak offered a clue as to its cause:

many of those who had fallen ill worked on pig farms, and pigs on these farms were also falling ill and dying. Analysis of samples from pigs and humans revealed that a previously unknown virus from the paramyxovirus family, the same family of viruses that causes measles, was responsible. The natural host of the virus was found to be the Malaysian flying fox, *Pteropus vampyrus*, a giant bat with a five-foot wing span that normally lives deep in the jungles of Southeast Asia, far from human civilization. However, these bats had been noticed eating mango fruit from the trees around the pig farms where the disease had broken out. After feasting on the fruit, the bats had dropped half-eaten mangos covered with their virus-laden saliva on to the ground. The pigs in turn had eaten the fruit and contracted the virus, which they had then passed on to workers on the farms.

What had prompted these normally forest-dwelling flying foxes to come so close to human habitation to feed? Researchers believe the most likely explanation is that the bats' unusual behaviour was triggered by smog from the forest fires the previous year. The smoke and the fire had prevented the fruit trees in the bat's normal habitat from flowering, so the bats had flown nearly a thousand kilometres to find food in the fruit trees of Perak.¹⁷ Like the apocryphal flap of the butterfly's wing in China that triggered a storm in New York, an event in the forests of Indonesia had led to the emergence of a new disease in Malaysia.

Human behaviour has led to the emergence of new diseases. Human technology, in the form of global air travel, has made it possible for these diseases to spread around the world faster than ever before. The greatest boon for viruses, bacteria and other micro-organisms seeking new hosts has been the rapid growth of air travel. As SARS demonstrated, the speed of modern air travel ensures that a virus that is in Hong Kong today can be carried by a sick traveller to any point in Southeast Asia within 3 or 4 hours, to Europe in 12 hours and to North America in 18 hours. Nearly 1.5 billion passengers travel by air every year, creating countless opportunities for diseases to spread rapidly across the globe.

Contrast this with the rate at which disease travelled in earlier centuries. In 1827, the second cholera pandemic of the nineteenth century broke out in India. It was carried to Afghanistan and the borders of Russia in 1827 by traders, and arrived in Moscow in 1830. Merchants then carried the disease to other European cities by 1831. Thanks to the recently introduced steamboat service across the Atlantic, the cholera bacteria reached North America in 1832 and spread through Canada and the US.¹⁸ The disease took five years to travel from India

to North America. Given this time frame, outbreaks in one part of the world had died down before the disease appeared in other parts of the world. If an epidemic of an equally virulent disease broke out today, it could cross the globe in less than a day, and every continent would be battling it simultaneously.

It is not only humans who transport disease-carrying organisms to new locations. Animals and plants do so as well, as a recent example from the US shows. In the 1990s, American pet owners who wanted something more exotic than the cat, dog or hamster owned by their neighbours but were not prepared to go as far as keeping a boa constrictor or an alligator found a happy alternative in the Gambian giant rat. These large rodents, native to large parts of Sub-Saharan Africa, were attractive enough in appearance (one website devoted to the creature gushed, "they have an absolutely adorable face, actually rather comical and whimsical in appearance. If you like rodents, they are sure to captivate you in a heartbeat"¹⁹) and sufficiently docile to become desirable novelty pets in the US.

In its natural environment, the Gambian giant rat, like every other living creature, is host to a variety of bacteria, viruses and other parasites that it has evolved with over generations and which cause it no harm. When the rats were transported over oceans and across continents, these microbes went with them.

In April 2003, a consignment of Gambian giant rats destined for pet shops in the US was shipped from Ghana to a dealer in Texas.²⁰ One of the rats was sold to a pet dealer in the Mid-West, who housed it together with a collection of prairie dogs, large rodents that normally live on the Great Plains of the US but have now been domesticated as pets.

On May 11, a 28-year-old Wisconsin woman, Tammy Kautzer, bought two of the prairie dogs for her three-year-old daughter Schyan.²¹ Two days later, one of the creatures fell sick, and its eyes began oozing fluid and later crusted over. The out-of-sorts animal also bit the little girl on her right index finger. The prairie dog became sicker and eventually died; the little girl developed a high fever and pox-like blisters formed on her head, hands and feet. Soon, her parents developed the same symptoms.

Public health authorities, who had been on the alert for possible terrorist attacks using biological weapons ever since the September 11 attacks, were alarmed by the fact that three people were showing symptoms that bore an eerie resemblance to smallpox, one of the diseases it was feared that potential terrorists could use.

Blood and tissue samples from the three patients were sent to the Centre for Diseases Control and Prevention (CDC) in Atlanta for analysis. The results contained good news as well as bad. The good news was that the disease was not smallpox. The worrying news was that these were the first reported cases outside Africa of monkeypox, a disease caused by a virus from the smallpox family. Monkeypox cases normally occur in isolated communities in the Central and West African rainforests. The virus lives in rainforest primates and squirrels and is passed on to humans through cuts and bites.

Working backwards, researchers found that one of the Gambian giant rats had infected the prairie dogs with the monkeypox virus, which had then passed it on to the human patients.²² Monkeypox is generally a mild disease, and Schyan and her parents survived little worse for their experience. But by the end of July 2003, there were over 70 suspected human cases in the US, all transmitted through contact with prairie dogs that had been infected by Gambian giant rats.

In today's globalized world it is increasingly easy for a virus to be transported out of its natural environment to new areas where it can spread and find new hosts to infect. The monkeypox virus from the rainforests of Central Africa has now found a potential new host among the large prairie dog population in the US. If the monkeypox virus and prairie dogs adapt to each other, the disease could become endemic in the US.

At least one exotic disease has already become endemic in the US in recent years, West Nile virus fever. In 1999, the first case of the fever, which is found in Uganda and Egypt, was reported in New York. By 2002, the virus, which is present in birds and other animals and transmitted to humans by mosquitoes, had spread to 44 states in the US, infecting 4000 people and killing 284.²³

These kinds of encounters between humans and viruses have been going on throughout human history.²⁴ At every stage of human evolution, new viruses have passed from animals to man. When hunter-gatherers learned to domesticate animals and began to settle in agricultural communities, viruses from cattle passed to humans, causing diseases like measles and smallpox. Later, as urban civilizations developed, the presence of tens of thousands of people living in close proximity to one another in towns and cities gave viruses the opportunity to infect large numbers of people rapidly in the form of epidemics. Now, our globalized world has made the spread of disease on a pandemic scale easier than ever before.

But if this process has been going on throughout human history,

what is there to be worried about? The emergence of a new virus in the human population is, for the reasons we saw earlier, marked by a particularly fierce battle between human host and virus, leading to huge loss of life. Over time, virus and host reach an accommodation, and the disease symptoms become progressively milder, or even disappear. Today, measles is a mild childhood disease. But when it first emerged in the human population, it was terrifyingly lethal. Over the centuries, it has become progressively milder as virus and host have co-evolved.

New viral diseases have emerged throughout history, and their emergence has often been accompanied by lethal epidemics. A new virus emerging today could cause the same kind of devastation that smallpox and measles caused in the Roman Empire and in other early civilizations. While the means at our disposal to fight disease are infinitely more sophisticated than they have ever been in human history, we are still uniquely vulnerable to viral diseases, as HIV/AIDS and Ebola have shown.

SARS was a warning to the world of what a new virus could do. Because it was transmitted easily from person to person, it was also able to take advantage of the speed of modern air travel and spread rapidly across the globe. The good news was that even though it spread relatively easily through droplets from infected persons, it did not spread as easily as some other diseases, such as influenza. The influenza virus can travel a relatively long distance through the air, and the average influenza sufferer infects at least 10 people. Droplet-borne SARS viruses, on the other hand, rarely travel more than several metres, restricting its transmission, with a few notable exceptions, to people who have been in close contact with a SARS patient.

SARS had a fatality rate of around 11 percent, high by the standards of most common diseases. The case fatality rate for normal strains of influenza, for example, is around 1 percent, and this is mostly among the elderly and infirm. But SARS was not as lethal as Ebola, which has a mortality rate of between 70 and 90 percent. The nightmare for the human race would be a new disease with the transmissibility of influenza and the lethality of Ebola. This would be a disease with the potential to spread widely and kill the majority of those who contracted it. This is the kind of pandemic that Lederberg and others have been warning of as a threat to human society.

The world was lucky with SARS. It was fairly lethal, but not uncontrollably so. It was fairly transmissible, but once again not uncontrollably so. Given the rate at which new infectious diseases have been cropping up, the probability that a virus that is more lethal and

more transmissible than SARS will emerge is increasing. The chapters that follow look at how SARS emerged, how it spread, how it was fought and its impact on the societies it hit the hardest. In understanding these issues, we are also gaining lessons on how to prevent a more lethal pandemic in the future.

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