



GERMS,
GENES,
&
CIVILIZATION

HOW EPIDEMICS
SHAPED WHO WE ARE
TODAY

DAVID P. CLARK

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This book is dedicated to my younger brother, Andrew, who has always enjoyed a good argument.

Contents

[Preface](#)

[Chapter 1: Introduction: our debt to disease](#)

[Epidemics select genetic alterations](#)

[Every cloud has a silver lining: our debt to disease](#)

[Crowding and culling](#)

[The message of this book](#)

[Chapter 2: Where did our diseases come from?](#)

[Africa: homeland of mankind and malaria](#)

[Many human diseases originated in animals](#)

[Are new diseases virulent to start with?](#)

[Diseases from rodents](#)

[Leprosy is a relatively new disease](#)

[What goes around comes around](#)

[Chapter 3: Transmission, overcrowding, and virulence](#)

[Virulence and the spread of disease](#)

[Infectious and noninfectious disease](#)

[Many diseases become milder with time](#)

[Development of genetic resistance to disease](#)

[Hunting and gathering](#)

[How do microorganisms become dangerous?](#)

[Chapter 4: Water, sewers, and empires](#)

[Introduction: the importance of biology](#)

[Irrigation helps agriculture but spreads germs](#)

[The class system, water, and infection](#)

[The origin of diarrheal diseases](#)

[Cholera comes from the Indian subcontinent](#)

[Cholera and the water supply](#)

[The rise and fall of the Indus Valley civilization](#)

[Cities are vulnerable to waterborne diseases](#)

[Cholera, typhoid, and cystic fibrosis](#)

[How did disease affect the rise of Rome?](#)

[How much did malaria contribute to the fall of Rome?](#)

[Uncivilized humans and unidentified diseases](#)

[Bubonic plague makes an appearance](#)

[Chapter 5: Meat and vegetables](#)

[Eating is hazardous to your health](#)

[Hygiene in the home](#)

[Cannibalism is hazardous to your health](#)

[Mad cow disease in England](#)

[The political response](#)

[Mad cow disease in humans](#)

[Fungal diseases and death in the countryside](#)

[Fungal diseases and cereal crops](#)

[Religious mania induced by fungi](#)

[Catastrophes caused by fungi](#)

[Human disease follows malnutrition](#)

[Coffee or tea?](#)

[Opportunistic fungal pathogens](#)

[Friend or enemy](#)

[Chapter 6: Pestilence and warfare](#)

[Who kills more?](#)

[Spread of disease by the military](#)

[Is it better to besiege or to be besieged?](#)

[Disease promotes imperial expansion](#)

[Protozoa help keep Africa black](#)

[Is bigger really better?](#)

[Disease versus enemy action](#)

[Typhus, warrior germ of the temperate zone](#)

[Jails, workhouses, and concentration camps](#)

[Germ warfare](#)

[Psychology, cost, and convenience](#)

[Anthrax as a biological weapon](#)

[Amateurs with biological weapons are rarely effective](#)

[Which agents are used in germ warfare?](#)

[World War I and II](#)

[Germ warfare against rabbits](#)

[Germ warfare is unreliable](#)

[Genetic engineering of diseases](#)

[Chapter 7: Venereal disease and sexual behavior](#)

[Venereal disease is embarrassing](#)

[Promiscuity, propaganda, and perception](#)

[The arrival of syphilis in Europe](#)

[Relation between venereal and skin infections](#)

[AIDS is an atypical venereal disease](#)

[Origin of AIDS among African apes and monkeys](#)

[Worldwide incidence and spread of AIDS](#)

[The Church, morality, and venereal infections](#)

[Moral and religious responses to AIDS](#)

[Public health and AIDS](#)

[Inherited resistance to AIDS](#)

[The ancient history of venereal disease](#)

[Chapter 8: Religion and tradition: health below or heaven above?](#)

[Religion and health care](#)

[Belief and expectation](#)

[Roman religion and epidemics](#)

[Infectious disease and early religious practices](#)

[Worms and serpents](#)

[Sumerians, Egyptians, and ancient Greece](#)

[Hygiene and religious purity](#)

[Protecting the living from the dead](#)

[Diverting evil spirits into animals](#)

[Cheaper rituals for the poor](#)

[Vampires, werewolves, and garlic](#)

[Divine retribution versus individual justice](#)

[The rise of Christianity](#)

[Coptic Christianity and malaria](#)

[Messianic Taoism during the collapse of Han China](#)

[Buddhism and smallpox in first-millennium Japan](#)

[The European Middle Ages and the Black Death](#)

[The Great Plague of London](#)

[Loss of Christian faith in industrial Europe](#)

[Cleanliness is next to godliness](#)

[Chapter 9: Manpower and slavery](#)

[Legacy of the last Ice Age](#)

[The New World before contact](#)

[Indigenous American infections](#)

[Lack of domesticated animals in America](#)

[The first epidemic in the Caribbean](#)

[Epidemics sweep the American mainland](#)

[The religious implications](#)

[Deliberate use of germ warfare](#)

[Slavery and African diseases](#)

[Exposure of islands to mainland diseases](#)

[Cholera and good intentions](#)

[The issue of biological isolation](#)

[Spotted fevers and rickettsias](#)

[The origins of typhus are uncertain](#)

[What about the Vikings?](#)

[Chapter 10: Urbanization and democracy](#)

[Cities as population sinks](#)

[Viral diseases in the city](#)

[Bacterial diseases in the city](#)

[The Black Death](#)

[Climatic changes: the “Little Ice Age”](#)

[The Black Death frees labor in Europe](#)

[Death rates and freedom in Europe](#)

[The Black Death and religion](#)

[The White Plague: tuberculosis](#)

[The rise of modern hygiene](#)

[The collapse of the European empires](#)

[Resistant people?](#)

[How clean is too clean?](#)

[Where are we now?](#)

Chapter 11: Emerging diseases and the future

[Pandemics and demographic collapse](#)

[The various types of emerging diseases](#)

[Changes in knowledge](#)

[Changes in the agent of disease](#)

[Changes in the human population](#)

[Changes in contact between victims and germs](#)

[The supposed re-emergence of tuberculosis](#)

[Diseases are constantly emerging](#)

[How dangerous are novel viruses?](#)

[Transmission of emerging viruses](#)

[Efficient transmission and genuine threats](#)

[The history and future of influenza](#)

[The great influenza epidemic of 1918–1919](#)

[Disease and the changing climate](#)

[Technology-borne diseases](#)

[Emergence of antibiotic resistance](#)

[Disease and the food supply](#)

[Overpopulation and microbial evolution](#)

[Predicting the future](#)

[Future emerging diseases](#)

[Gloom and doom or a happy ending?](#)

Further reading

Index

Preface

Humans typically labor under the illusion that they control their own destiny. This book argues that, in reality, invisible microbes often control human activities. Recent findings have shown that animals that develop without their natural bacterial inhabitants have defective immune systems and poor health. Thus, we and other animals depend on the bacteria for our healthy development. On a large scale, we now recognize that microbes maintain the global ecosystem and are partly responsible for keeping our planet healthy. The amount of “good” bacteria that work to recycle nutrients and degrade waste is greater by far than the amount of “bad” bacteria that threaten human health.

Here I enter the intermediate zone between individual development and planetary ecology, to discuss how microbes have decided major historical events and shaped cultural trends. Furthermore, the emergence of resistance to infectious diseases has selected alterations in genes that affect human behavior.

This book is *not* a history of public health, medicine, or microbiology, although it does mention these issues. Instead, this book describes how infections have shaped both individual humans and the societies from the very beginning of civilization. Disease has influenced our cultural and religious beliefs, as well as determined the outcome of wars and major historical events. I have tried to show how beneficial long-term effects have resulted from epidemics that were terrible tragedies to those caught up in them.

Philosophically, we are just emerging from a period of transition between the perfectionist and selfish views of nature. The classic example, in the area of disease, is the idea that, over the ages, infectious agents will adapt to their hosts. Eventually, all diseases will become no worse than a bad cold. This is an attempt to retain a utopian future while allowing evolution to occur. Recently, we have come to realize that although some diseases become milder, others might evolve with greater virulence. We now see nature more as an arms race between life forms deploying assorted genetic strategies.

A second aspect of this more modern viewpoint, is to realize that the scale on which we view events is important. Improving a species through evolution inevitably involves the death of many less fit individuals. Applying this Darwinian idea to human populations lets us see that whereas many fatalities from a plague are tragedies at the personal level, they can have positive effects when seen from a long-term perspective.

These positive effects vary from genetic changes that make us more resistant to the disease responsible for the epidemic (and often to related infections), to effects on human society that are hard to pin down and quantify. Epidemics have undoubtedly affected the outcome of many wars and conflicts. Whether these interventions were a good thing obviously depends on which side you support. Less ambiguous is the contribution of epidemics to the development of a free, technological, market-based society in the West. More ambiguous are the possible effects on religious belief and human behavior.

Modern progress in DNA technology and human genetics is generating a vast amount of data. Analyzing and checking this will take time. The next few years should reveal many connections between infection, disease resistance, and alterations in genes that affect not only our physical characteristics, but also brain function or development and thus impact human behavior. We live in exciting times!

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About the Author

David Clark was born June 1952 in Croydon, a London suburb. After winning a scholarship to Christ's College, Cambridge, he received his Bachelor of Arts degree in 1973. In 1977, he earned his Ph.D. from Bristol University for work on antibiotic resistance. David then left England for postdoctoral research at Yale and then the University of Illinois. He joined the faculty of Southern Illinois University in 1981 and is now a professor in the Microbiology Department. In 1991, he visited Sheffield University, England, as a Royal Society Guest Research Fellow. The U.S. Department of Energy funded David's research into the genetics and regulation of bacterial fermentation from 1981 till 2007. David has published more than 70 articles in scientific journals and graduated more than 200 masters and Ph.D. students. He is unmarried and lives with two cats: Little George, who is orange, and Ralph, who is mostly black and eats cardboard. David is the author of *Molecular Biology Made Simple and Fun*, now in its third edition, as well as three more serious textbooks.

1. Introduction: our debt to disease

Early in the fifth century A.D., the Huns, led by Attila, emerged from the Asian steppes and swept across Europe. They faced no serious resistance. What was left of the greatest civilization the world had seen, the Roman Empire, was a tottering wreck. One more good shove and the remains of Roman civilization would have taken a final nose-dive. But strangely, on the verge of storming Rome itself, Attila withdrew. Why?

For many centuries the official answer was that God had intervened in some mysterious way to protect his chosen city, Rome, seat of the papacy. In more recent times, such supernatural explanations have fallen out of favor and the question has arisen anew. Some have suggested that Attila was overawed by the sanctity of Rome. But why would a pagan warlord like Attila stand in awe of a Christian center? Attila was by no means an ignorant barbarian: For example, he invited Roman and Greek engineers into Hun territory to install bathing facilities. However, his respect for Roman civilization was clearly of a pragmatic rather than a religious nature. Another theory is that Attila was worried about leaving unattended his newly acquired homeland, in what is now Hungary. But then why did he venture on almost as far as Rome and hang around indecisively for so long before returning? All these explanations founder on the same point. It seems clear that Attila did indeed set out with every intention of taking Rome, but his expedition came to a premature halt.

Mounting modern evidence suggests that Attila was stopped by a virulent epidemic of dysentery, or some similar disease. Most of his men were too ill to stay on their horses, and a significant number died. In short, bacteria saved Rome. The ancient world had no knowledge of bacteria. Instead, most ancient cultures believed that epidemics were one of the main ways the gods expressed their displeasure. In the Bible, pestilence is often a punishment for wickedness, both for disobedience by the Israelites themselves and for intrusions by outsiders. For example, an epidemic saved the holy city of Jerusalem from the Assyrian invaders, providing a precedent for the failure of Attila to take Rome. So, in a curious way, the earlier explanation of God preserving Rome has reemerged in a modern scientific guise.

But before we rush to enroll the bacteria as honorary Roman citizens, we must consider another aspect of the issue. A major reason Rome itself was in such disarray when Attila approached was that it, too, had fallen victim to pestilence. Several catastrophic epidemics had swept through Rome in the period before the Huns surged into Europe. So whose side were the microbes really on?

Nowadays, floods, earthquakes, and volcanic eruptions are regarded as “acts of God,” at least by insurance companies. The implication is that neither the victims nor anyone else is responsible. That is not entirely true. People who persistently rebuild their homes on a flood plain or along a fault line are at least partly to blame. Similarly, epidemics do not just happen to anyone at anytime anywhere without good reason. Neither the epidemics that struck Rome nor the disaster that overcame Attila and his Huns were just random outbreaks of disease. What’s more, their origins were interrelated.

Before Attila, Rome had several narrow escapes from other hordes of barbarians. Several times looked as if the end was near and that the Romans would be overwhelmed. Yet somehow the Romans scraped by. Part of the credit must go to the Romans, who were an unusually determined people, not prone to giving up easily. Yet much of the credit also belongs to the unseen and unsung legions of microbes. It is relatively easy for us today to understand why an overcrowded, unhygienic ancient city suffered from persistent outbreaks of pestilence. Why disease so often intervened to protect the same city from successive waves of barbarians is more difficult to understand.

Imagine an ancient society that is moving along the path to urbanization. Large numbers of people are crowding into a growing city, such as Babylon, Athens, or Rome, which is much larger than neighboring communities. Infections normally spread more efficiently through crowded cities than through sparsely populated villages and rural areas. Sooner or later, some pestilence or plague will strike the emerging city. Its population will be decimated, and for a while it will be vulnerable. But when it recovers, its population will consist largely of those who are resistant to the plague of the day. In other words, denser populations are the first to build up resistance to the current infectious diseases of their region of the world. Next time a major conflict arises, the movements of armies or of refugees will spread infection around the war zone. People from rural communities or smaller towns will have built up less resistance than the population of the city-state, so pestilence will fight on the side of the biggest city.

Once a major population center gains a significant lead over its competitors, the pestilence factor will make it extremely difficult to overthrow. This indeed is what happened to ancient Rome. A series of epidemics whose identities remain unknown devastated the Romans early in their history. Later barbarians who ventured too close to Rome routinely succumbed to massive epidemics that had only mild effects on the Romans. As long as the Huns retained their nomadic lifestyle, they would have been little affected by epidemics. Even if an occasional marauder caught some infection from more settled and crowded regions, it was difficult for pestilence to spread among small, scattered groups of nomads. Once the Huns aggregated into a horde, under centralized leadership, the situation changed radically. On the one hand, they had little previous exposure to pestilence, so they lacked resistance. On the other hand they now formed a large, dense population, ripe for the spread of invading microorganisms. In a way, Attila's tragedy was the result of this vulnerable intermediate situation between nomadism and urbanization.

The general principle that *pestilence favors societies that have become resistant because of prior infection* has had a vast effect on human history. It has not only directed the growth and survival of the empires of the Old World, but it also was the major factor in European invaders' takeover of the American continent.

Epidemics select genetic alterations

Another result of ancient epidemics that experts have only recently come to understand is the accumulation of alterations in the human genome. Through the millennia, a never-ending stream of hostile microbes has attacked and decimated human populations. Each time a human population is devastated by infectious disease, genetic selection takes place. People carrying genetic alterations that

confer resistance, even if only partially, have a greater chance of survival. Consequently, the descendents will make up a greater proportion of the surviving population.

The result of constant epidemics is that, over the ages, distinct acquired genetic changes now protect us against many individual infections. We still carry these modifications in our DNA sequences, and recent investigations are revealing a steady stream of such genetic alterations, many surprising recent. Thus, in many ways, we are what disease has made us.

Yet another convoluted twist of fate appears here. Several well-known hereditary defects turn out to be side effects of resistance to disease. For example, sickle cell anemia is the result of hereditary resistance to malaria, and cystic fibrosis is associated with resistance to intestinal diseases that cause diarrhea and dehydration. A single copy of the cystic fibrosis mutation reduces water loss, thus protecting against a range of diseases whose most dangerous effect is dehydration. Two copies of the cystic fibrosis mutation slow water movements in the lung too much. So one copy of the mutation protects against disease, and two copies of the same mutation cause a hereditary defect.

The case of cystic fibrosis is especially revealing. The cystic fibrosis mutation is unusually common in those of northwest European ancestry. Calculations based on mutation rates and population genetics suggest that these mutations arose shortly after the collapse of the Roman Empire. This collapse led to a massive loss of general hygiene, especially in the water supply. Doubtless waterborne intestinal diseases spread like wildfire, and eventually, mutations providing resistance accumulated.

Every cloud has a silver lining: our debt to disease

The way epidemics have intervened in history shows that disease is not just a uniformly negative matter. The outcome of an epidemic may be quite complex, especially over the long term. Whether we regard any particular outcome as “good” or “bad” depends partly whose side we are on and partly on the relative weight we give to short-term versus long-term effects. In this book, I point out the positive effects of epidemics. This is not because disease is beneficial overall, but because these less obvious beneficial side effects often are overlooked. If a virulent plague rages through society, the obvious response is to stop it by whatever means possible, not to sit around fantasizing about its effects on future centuries.

Not surprisingly, we normally think of infectious disease as our enemy. When a successful program of vaccination wipes out a blight such as smallpox, we feel no remorse that a unique life form has suffered extinction. When we learn that throughout the course of human history infectious disease has been responsible for more deaths than war, famine, or any other cause, this only confirms our viewpoint. Indeed, the victories we have achieved over infectious disease are among modern man's greatest triumphs. Today industrialized nations have largely brought infectious disease under control. Unlike our predecessors of only a century or two ago, nowadays we mostly die from heart disease and cancer. Our longer lives give us time to reflect on the other side of this issue, and I argue that paradoxically, we also owe a great debt to infectious disease.

This approach is not merely idle intellectual self-indulgence. Infections that still threaten us either

tend to cause disease in a subtler manner, or else they remain dangerous for other complicated reasons. The classic modern-day example is AIDS. This disease does not actually kill directly. Instead, it damages the immune system, allowing other diseases, impotent by themselves, to gain a foothold. Perhaps it is time for humanity to also take a more indirect and subversive attitude.

Over the long term, a positive side to disease emerges. Granted, if large black swellings are appearing in your armpits and you're about to die of bubonic plague, you'll find it difficult to maintain an unbiased perspective. Nonetheless, although the Black Death epidemics that ravaged Europe in the Middle Ages were devastating at the time, they had beneficial effects on a more global and futurist scale. They shook up the repressive feudal system and, in the long term, made a major contribution to the evolution of Western democracy.

On the negative side of the balance sheet, we have the millions who died painful deaths in the plague epidemics. On the positive side, we must not forget those other millions who would have died in misery and poverty if industrial democracy had been delayed significantly. In our horrified emotional reaction to epidemics, we normally forget this latter aspect. We do not know for sure how many children would have died in infancy each century if the feudal system had continued. However, if we compare the infant mortality of 30%–50% that prevailed before industrial democracy with the less than 1% infant mortality of today, we can clearly see that millions of innocent lives have indeed been saved.

On a more individual level, Charles Darwin probably caught Chagas's disease while on his famous voyage on the *Beagle* around South America and the Galapagos Islands. His resulting poor health kept Darwin at home for much of the rest of his life. Instead of wandering off on more expeditions to observe nature and collect specimens, he stayed put and pondered the origins of living things. This may well have played a major role in Darwin's compilation of the most influential book of the last few centuries, *The Origin of Species*.

As already remarked, whether such indirect effects are “good” or “bad” depends on your perspective. Should we consider the happiness of the individual, the benefit to a particular group, or the overall betterment of mankind? For that matter, how do we define the “betterment” of mankind? Whatever your outlook, the effects of infectious disease have been undeniably important in changing the course of history. Perhaps it is not too fanciful to think of “good” and “bad” diseases. Some diseases, like bubonic plague, may have had some beneficial long-term side effects on human society as a whole. Others, like sleeping sickness, have no positive aspect. Whatever our moral perspective, the effects of an epidemic on the overall fortune of a tribe, nation, or even a whole continent may be quite different than the immediate effects on the victims.

Crowding and culling

Pestilence has molded both our cultures and our genes over the long term. But before tackling the long-term effects, let's look at what actually happened to human civilizations when diseases struck. Over time, humans increased in numbers and gathered together in villages, towns, and then cities. Populations grew larger and denser as civilization progressed. Sooner or later, when people a

crowded together, infectious disease takes the opportunity to spread itself around, too.

Let's focus on severe infections with high mortality rates (such as smallpox, Ebolavirus, or bubonic plague). Each time pestilence passes through society, a sizable fraction is wiped out. The survivors give birth to the next generation, and numbers gradually increase again. Once the population is dense enough, another epidemic strikes and the cycle repeats. Over many generations, genetic resistance develops, so virulent pestilences wane into childhood diseases and may eventually fade away completely. Meanwhile, novel infections emerge and spread, taking the place of yesterday's retired plagues.

A crucial point for understanding the long-term effects of an epidemic is that death is distributed neither equally nor at random. Infectious disease strikes harder at some segments of the population than others. Let's start with factors that are wholly or mostly biological in nature.

First, older people and young children are especially susceptible. This is because the human immune system is not fully developed in the very young and is beginning to fade away in the very old. Conversely, some individuals may be immune to certain infections. Nowadays, such immunity is mostly due to artificial vaccination. Before this was available, immunity was normally acquired the hard way by catching the disease and surviving.

Second is the phenomenon of genetic resistance to disease. In contrast to immunity, which is acquired during an individual's lifetime, genetically based resistance is inherited from one's ancestors. Individual people differ greatly in their inherent susceptibility to different diseases. When a population suffers from a dangerous disease, those with genetically based resistance survive more often than others. Consequently, inherited resistance gradually builds up over several generations. For example, the earliest reliable accounts of smallpox in Asia and Europe suggest that it was fatal 75% or more of the time. Yet over the next thousand years, the mortality rate fell to around 10%–30%. The first time smallpox was carried to the New World, the mortality rate among the American Indians was 75% or more. Thus, a virulent disease is vastly more devastating in a population that has never been previously exposed and has had no opportunity to build up resistance.

Many other factors affect our susceptibility to disease. These range from mainly biological to largely social in nature. For example, those who are poorly fed or live in bad housing and are cold, wet, and dirty are much more at risk than well-fed people who are dry, warm, and clean. Obviously, the closer people are crowded together, the easier it is for infectious disease to spread. These factors all lie on the interface where social conditions merge with biological effects.

Many of these factors can be lumped together, at least crudely. To put it bluntly, poor people are both more likely to become infected and also more likely to die if they are infected. Unfair as it may be, this is inevitably true in all real-life human societies. Today this is most clearly seen in the contrast between the industrial nations and the Third World. However, throughout recorded history prosperity and status have had their advantages. Even in societies of apes and baboons, higher-status animals tend to be better fed, a factor that helps them fight off many infections.

But how do you get to be rich or poor, high or low? To be sure, one way is to inherit money or social position (as distinct from genes) from your parents. But this ignores how your ancestors got rich

start with. Do competent, industrious, attractive, healthy, and brave people tend to rise through the ranks of society? Or is it the ruthless, greedy, cowardly, and corrupt who claw their way to the top? Whichever of these alternatives you espouse, for better or for worse, during a virulent epidemic, fewer people at the top will die than those at the bottom.

The message of this book

Humans typically labor under the illusion that they control their own destiny. However, I argue in this book that infectious disease has had a massive unrecognized effect on human history and culture. Moreover, constant epidemics with high death tolls have occurred throughout history and have selected major genetic alterations in the survivors. Modern DNA analysis, including the recent Human Genome Project, has revealed that alterations have occurred in certain individual genes. But many more changes remain to be discovered.

Some of these genetic alterations have mainly physical effects, but others may affect brain and behavior. For example, it is possible, though not fully proven, that genetic alterations that predispose humans to schizophrenia also protect against viral infections. As yet, the genes presumed responsible have not been identified.

Before dealing with these issues, we need to understand that many of our infectious diseases have emerged only very recently, after humans developed agriculture and settled into towns and cities (as discussed in [Chapter 2](#), “[Where Did Our Diseases Come From?](#)”). We also need to realize that a disease’s mode of transmission can alter its virulence over a relatively short period of historical time (as discussed in [Chapter 3](#), “[Transmission, Overcrowding, and Virulence](#)”).

2. Where did our diseases come from?

Africa: homeland of mankind and malaria

Africa is the ancestral homeland of mankind. Our species originated there perhaps 100,000 years ago. From Africa, humans spread through the Middle East and around the world. Not surprisingly, most of our original diseases evolved alongside (or inside) their human hosts in Africa, so the human race grew up in constant contact with parasites such as trypanosomes, which cause sleeping sickness, and *Plasmodium*, which causes malaria.

Many diseases adapted to tropical conditions were left behind by those who migrated to colder regions. In particular, many parasites that need a warm climate failed to adapt to the temperate zone. Conditions inside the human body remain fairly constant. Consequently, the susceptibility of a disease agent to climate depends on how much time it spends outside the body between infections. Bacteria and viruses that are passed directly from person to person are affected little. Parasitic worms whose larvae develop in rivers or lakes before reinfesting human hosts are highly susceptible. Diseases that rely on insects to spread them are greatly affected by climate because their insect vectors often cannot survive colder winters. Thus, mankind left behind malaria, sleeping sickness, yellow fever, and many other insect-borne diseases when we emerged from the tropics.

These diseases are still a major problem in tropical regions. According to the World Health Organization (WHO), some 500 million clinically observed cases of malaria cause a little over a million deaths each year, the majority in Africa. Of these deaths, about half are of children younger than five years old. Recently, AIDS overtook malaria and tuberculosis to become the leading cause of death among the infectious diseases, with around three million deaths. (Diarrheal disease and respiratory infections still head the mortality tables, but these are each due to several different infectious agents.) Tuberculosis kills around 1.5 million victims per year, slightly more than malaria. However, these deaths result from about 10 million cases, far fewer than the 500 million cases of malaria. Relatively few malaria victims die outright. Instead, they suffer life-long debilitation, which not only lowers their productivity, but also makes them vulnerable to other infections.

How important was malaria?

Malaria is sometimes quoted as having killed more people than all the wars and all the plagues recorded in human history. But although infectious disease as a whole has undoubtedly killed far more people than warfare, little compelling evidence indicates that malaria has outperformed all other infectious diseases. Although malaria has taken a steady death toll in Africa and other tropical zones, it was absent on the American continent until European colonization. Furthermore, although malaria

nibbled at the heels of Europe until recently by infesting marshlands, the dense urban populations temperate Europe and Asia were fairly unaffected. Moreover, until the recent population explosion, the population density of Africa and other tropical regions where malaria is endemic was relatively sparse.

Even in Africa, the evolutionary homeland of both man and his earliest diseases, was malaria really the number one killer before the last few centuries? Today *Plasmodium falciparum* causes most lethal attacks of malaria, whereas the other three species of malaria cause relatively milder disease and are rarely lethal. Although *P. falciparum* is presently spreading from Africa around the tropical world, the sickle cell mutation that provides resistance is found only in Africans indigenous to regions harboring *P. falciparum* malaria. The fact that the sickle cell trait is so harmful by itself suggests that it is a recent, emergency, evolutionary adaptation. Over longer periods, we would expect the build-up of resistance with less deleterious side effects, as is the case for many other diseases, including the milder variants of malaria. This suggests that the malignant, falciparum form of malaria is of relatively recent origin and that, even in Africa, malaria was present in its milder forms for much of early human history.

Moreover, in precolonial Africa, many other diseases that have since been largely eradicated due to Western technology were still active. Relative to malaria, yellow fever may be trivial today, but in the early colonial period, sailors to tropical parts feared it at least as much. Again, among many West African tribes, smallpox, which has now been completely eradicated, was historically feared the most. Although malaria has survived the onslaught of modern technology better, this does not necessarily mean it was the major killer before other diseases were brought under control.

Our fellow travelers

Malaria is the best known example of a disease that has accompanied our species from its earliest beginnings and remains a major health problem. However, it is by no means the only disease to have accompanied us since our origin. Tuberculosis, herpes, and typhoid are other well-known examples. This raises the issue of how an infectious disease avoids getting left behind when its human victims consist only of small, scattered bands.

Consider first a “recent” disease such as measles. This humans-only disease is highly contagious and is spread from human to human without relying on any insects or other carriers. After recovery, humans gain immunity from measles. Consequently, measles faces the problem of constantly finding fresh victims. When measles has finished infecting all members of a small isolated tribe, it has nowhere to go. Thus, diseases such as measles cannot persist unless civilization provides a dense, packed crowd of victims. Clearly, measles is not one of our original diseases; we consider its origin later.

One way for a disease to avoid the predicament of measles is to be shared among multiple animal species. Malaria and sleeping sickness are examples of this approach. Another approach is to remain dormant inside a host until fresh victims are available. Herpes, caused by a virus, and typhoid and tuberculosis, caused by bacteria, have all taken this route. Viruses of the herpes family may lie quiescent in nerve

cells for years until provoked by stress to emerge. They may then spread to new victims. Typhoid can hide in the gall bladder of human hosts who show no symptoms but are a constant source of infection to others. Tuberculosis, caused by *Mycobacterium tuberculosis*, hibernates in the lungs.

Human remains showing signs characteristic of tuberculosis (TB) have been found dating as early as the Neolithic period, when settled agricultural communities first appeared (9,000 B.C. onward). X-rays of Peruvian mummies dating to before the European conquest show signs of tuberculosis, implying that the American Indians brought TB with them when they crossed the Bering Straits some 10,000–15,000 years ago. Extraction of DNA characteristic of *Mycobacterium tuberculosis* from some of these mummies has confirmed that it really was tuberculosis. The signs of TB in the skull of a half-million-year-old *Homo erectus* from Turkey are vastly more ancient.

It was once thought that tuberculosis might have moved into the human population from cattle, which suffer from a closely related form of the disease. However, recent DNA analysis suggests the reverse—that we humans transmitted tuberculosis to cows after domestication.

Many human diseases originated in animals

Despite the new DNA evidence that exonerates the cow from spreading tuberculosis, most of our present infections probably did originate from other animals. It seems likely that prehistoric hunter-gatherers were relatively free of infectious diseases, compared with historical and present-day man. The unusual susceptibility of American Indians to most diseases brought across the Atlantic from the Old World argues that the indigenous people of the American continent had never been exposed to these diseases. This implies that these diseases emerged after the ancestral American Indians split off from their Asian relatives approximately 15,000 years ago. Because the migrating tribes evidently did not import them into America, it seems that smallpox, measles, and so forth must have been human diseases for less than 15,000 years—perhaps less, even, than that.

Before rushing forward, a word of caution is in order. We are fairly sure that malaria is an ancient disease. However, malaria was not present among American Indians before contact with the Old World was reestablished. The reason is that malaria is carried by mosquitoes, which failed to survive when humans migrated from the tropics into the colder regions of Asia. The Asian ancestors of the American Indians had therefore left malaria behind before they entered the American continent. When invoking New World susceptibility for the age of a disease, we must keep this factor in mind. Other tropical diseases that cannot persist in colder climates may also be ancient despite not being carried to the Americas.

Note also that, apart from the domestic dog, the American Indians lacked the domestic animals characteristic of the Old World. When the Bering Strait was crossed, cattle, sheep, horses, and pigs had not yet been domesticated by the tribes who made the crossing. Many human diseases have come from these animals. Because the first humans to colonize the Americas did not take these animals along, they could not have caught their diseases after migrating.

As humans expanded around the globe and populations grew ever denser, our species became a living

paradise for infectious disease. No other large animal in the known history of our planet has provided such crowds of individuals, packed closely together, just waiting for some pestilence to move in and multiply. Over the ages, infectious diseases have migrated from their original hosts whenever they made contact with the human species. Animals that have the closest relationships with humans have been the source of most diseases. This includes not just the deliberately domesticated animals, but also the rats and mice that have taken up residence in and around human settlements. Even today most human towns and cities are home to more rodents than humans.

Dense herds of domestic animals and fields of closely planted crops have provided similar opportunities for colonization by diseases from related wild animals and plants. Some of these, in turn, have moved on to humans. Today, as the remaining jungles and rain forests are being explored and exploited, they have yielded more novel diseases. Lassa fever, Hantavirus, and Ebolavirus have all made the jump to man, the ubiquitous host. Although mankind has done a good job of exterminating other larger animals, we have kept many of their diseases.

Recent diseases from animals

When Hippocrates compiled his treatise in the fifth century B.C., the ancient Greeks did not know smallpox, measles, bubonic plague (an Asian disease), syphilis (an American import), yellow fever (from Africa), or leprosy. They were aware of herpes, typhoid and/or typhus, tetanus, amoebic dysentery, rheumatic fever, chlamydia (both venereal and trachoma), and gonorrhea (or something very similar).

Zhouhou Beijifang, written by Ge Hong in fourth-century-A.D. China, lists malaria, erysipelas, typhoid, dysentery, and cholera. In contrast to the ancient Greeks, leprosy and smallpox were not known, implying that these appeared roughly 2,000 years ago. These records, together with a variety of other ancient accounts, suggest that many diseases we are familiar with today were absent in earlier historical times and have appeared only within the last thousand years or so.

Viral diseases, which colonized humans only after civilization provided sufficiently crowded victims, include mumps, measles, German measles, smallpox, polio, influenza, and even the common cold. At least our hunter-gatherer forefathers didn't have to worry about scaring away the game with violent sneezing! These viral diseases all have close relatives in various animals. After making the jump to humans, they adapted over the centuries to their new hosts and, in many cases, lost the ability to infect their original hosts. For several of these diseases, evidence suggests that they were originally more virulent and have become milder over the years.

For all these diseases, victims who recover become immune. Consequently, these viruses must keep moving through a constant supply of new hosts. Flu and colds do return year after year and reinfect the same people, but each successive epidemic comes from a newly evolved strain of virus. Although you may be reinfected with such new strains, you remain permanently immune to variants of flu or cold viruses from previous years.

Smallpox is a good candidate for a very recent addition to humanity's panorama of parasites. It was

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